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# <u>Nevada</u>

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<del>r 20</del>00

ed by

. J. Sully<sup>1</sup>, L. E. Barker<sup>1</sup>, and B. A. Moore<sup>2</sup>

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Office



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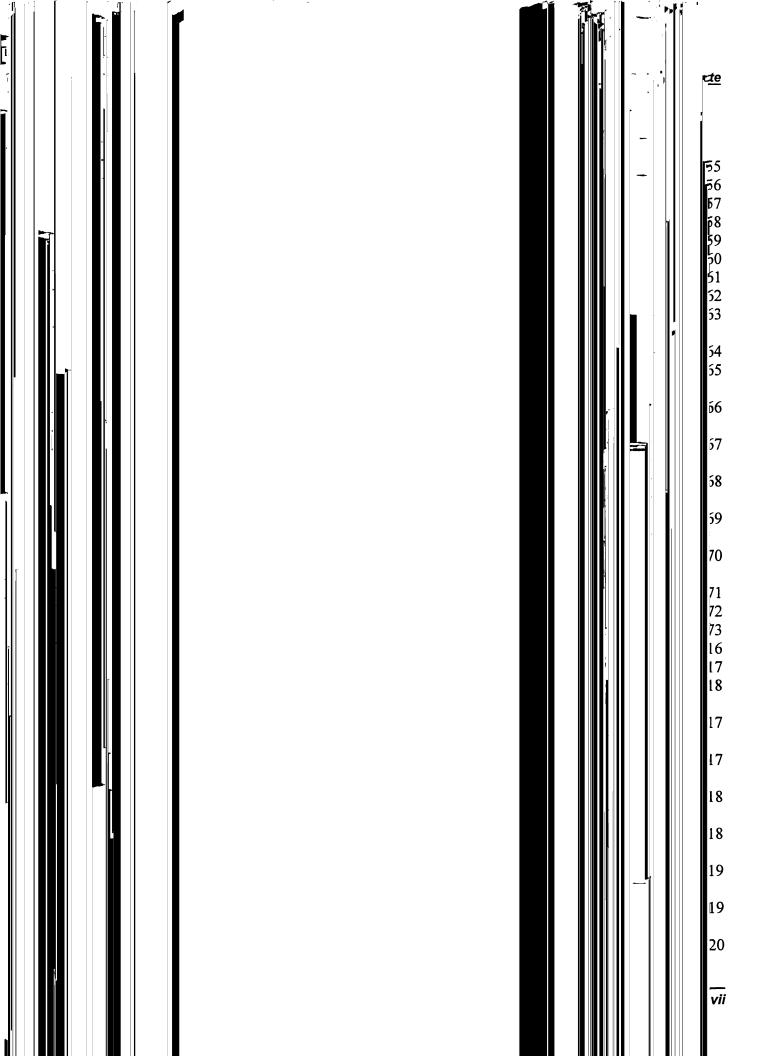
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## ACRONYMS and ABBREVIATIONS

Energy Commission
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nean aerodynamic diameter
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nit month

angle Y

of Land Management
el

ite Analysis
e action investigation
e action site
e action unit
pensive Environmental

nensive Environmental Response, Compensation, and Liability Act Federal Regulations

er oint

partment of Commerce partment of Energy partment of Energy/Nevada Operations Office partment of the Interior ality Objective esearch Institute

nental Impact Statement ironmental Protection Agency

Emergency Management Agency Facilities Agreement and Consent Order

ar

Zero

water

#### **ACRONYMS and ABBREVIATIONS**

International Council on Radiation Protection inadvertent human intruder
Industrial Source Complex
Industrial Source Complex Short-Term

LT Industrial Source Complex Snort-Term
LT Industrial Source Complex Long-Term

thousand years ago kilogram kilometer

liter

Low-Level Waste

VL Local Meteoric Water Line

S Low-Level Waste Inventory System

meter million

million years ago mixed fission products

mile millimeter

member of the public

mega Pascals
miles per hour
millirem

millirem

nasopharyngeal

Nevada Administrative Code Nevada Applied Ecology Group

R Nellis Air Force Range

A National Aeronautics and Space Administration

P National Council on Radiation Protection and Measurements

AA National Oceanic and Atmospheric Administration

Nuclear Regulatory Commission
Nuclear Rocket Development Area

Nevada Revised Statutes

Nevada Test Site

Performance Assessment

P Performance Assurance Management Plan

picoCurie

F pathway dose conversion factor

potential evaporation

potential evapotranspiration

precipitation









#### **ACRONYMS and ABBREVIATIONS**

RCRA Resource Conservation and Recovery Act
REECo Reynolds Electrical & Engineering Co., Inc.
RI/FS Remedial Investigation/Feasibility Study

RIDP Radionuclide Inventory and Distribution Program
RREMP Routine Radiological Environmental Monitoring Plan

RWMS Radioactive Waste Management Site

s second

SAIC Science Applications International Corporation

SDCF scenario dose conversion factor

SME subject matter expert

SMOW standard mean ocean water

STAR stability array

Sv Sievert

TEDE Total Effective Dose Equivalent

TRU transuranic

UGTA Underground Test Area USGS U.S. Geological Survey

WAC waste acceptance criteria

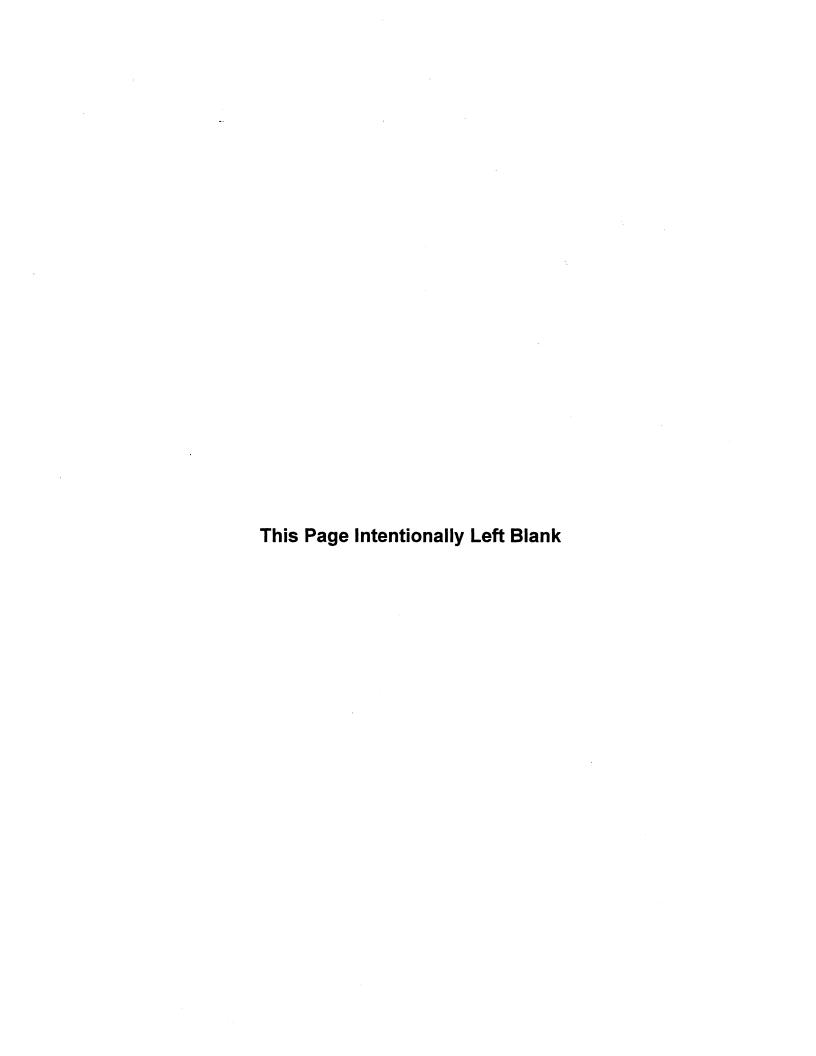
WMDB Waste Management Data Base

yr year









<u>Site</u> ne ınd ly nent a has nd (40 lon e xiii

at Human Intruder

#### **Compliance Period**

Water

Closure - 1,000 years

250 - 1,000 years

250 - 1,000 years

waste and resides within the rds are set for short-term (acute)

primary dose limit and Presiding at any location where exceed the 100 mrem/yr dose int, an options analysis is required

d is based on the elicitation of an n (Black et al., 2000). A panel ty of various lengths of instituriod of institutional control is Flat during this period. After (330-ft) site boundary and the eriod is assumed to continue to ).

ed bulk LLW from on-site and alk wastes have been disposed in pression created by the detonation Two pairs of adjacent craters from the original five craters. In a U-3bh. Waste is placed in the ated by 1-m- (3-ft)-thick layers of

to 1987. On a volume basis, om the cleanup of atmospheric it is estimated to have contained te at the time of its operational

a Assessment/Composite Analysis

## ida Test Site

Because ments of

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7 20 percent
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ed LLW
contain
13. Major
Pu. The

gent. At ized soil 3 sites. cted. The m<sup>3</sup> activity require-

e of the of radioni]) to the pe climate at mm) ım (64 in.). site does ement he alluvium rater content r 50 m surface. 0 ft) of oth of 1,614 ft) stential for the

. Past ucca Flat. ar tests are oil Sites.

cca Flat, known as approximately 3e8 Ci of

### ance

exclude the MOP from Yucca. Prior to the loss of instile, based on the great s, the MOP is assumed to significant exposure of the at this time.

ts at the Area 3 RWMS that 20.2A. Each disposal unit is sosal unit conceptual model e material. The source term different release and trans-

Subsidence and erosion are ses cracks to form in the cap nuclides. The subsided cap is 1, causing increased infiltraation events is expected to atmosphere by evaporation to be the norm at the site will water during drying periods ents may pond in the in to drain to the aquifer, water. Analysis of the is unlikely to transfer impliance period. Therefore, be the bounding case for the ection of solutes, nonvolatile uptake and burrowing

by gaseous diffusion through uclides is limited to the total

it, 100 m (330 ft) from the site a week at a remote site. The IS through inhalation of soil

sessment/Composite Analysis

# da Test Site

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ike the l area culture g a s that the osal unit. ation area intrusion

posal sites. nding urces. The ider intruder

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of Monte
jectives to

ination at or from clear at of the lled. The Area 3 will be

g in the tivity in ed in the n at Soil tmospheric he MOP is atmonvolatile

ime processes as assumed in the PA. for exposure to contaminated

ations directly incorporating c mean of a large number of Monte against the performance objectives to

## alysis

tives for a period of 1,000 years after the MOP at 100 m (230 ft) from the as <sup>3</sup>H, <sup>90</sup>Sr, and <sup>137</sup>Cs decay. After a By 1,000 years, the mean TEDE and U-3ah/at.

atmospheric pathway behaves eceived through the atmospheric J-3bh by 000 years after closure.

iod. The fluxes expected are quite rred at U-3ah/at at 1,000 years after

aquifer within 1,000 years. tected for a period of at least 1,000

eases of radioactive materials from ptions are not likely to be consistent

iway are determined predominantly ide release model is most sensitive to vity. The volatile radionuclide release ree of atmospheric dispersion hways analysis is sensitive to the f the institutional control period. The occurrence of agriculture and the insensitive to the occurrence of cracks

## Nevada Test Site

#### t Result

#### ent Result

#### Maximum

6e-2 mrem/yr

2e-2 mrem/yr

1e-1 pCi/m²/s

NA



8 mrem/yr

ntory and the radon cap cracking. rmance objectives

ating uncertainty
ults for the
less than the
compliance with the
n institutional
riculture increases
f the institutional
n below the

ected for the in the intruder-rom the site. The te in the cap soil. ,000 years. The waste in the drill. After a few d to be bability of occur-

## ysis/Results of Analysis

or the MOP from exposure to all sources of residual radioactive y less than 30 mrem/yr. The mean value of the TEDE was estimated to ears. The TEDE decreases throughout the compliance period and is ars. Greater than 80 percent of the dose is attributable to residual mospheric testing at Soil Sites. Greater than 60 percent of the dose is RNET GZ Soil Site at the RWMS boundary. Initially, the TEDE Sr, <sup>137</sup>Cs, and <sup>152</sup>Eu in soil at the HORNET GZ decays. After a few DE declines slowly. During this period, the dose is controlled slow radioactive decay of <sup>239</sup>Pu, <sup>240</sup>Pu, and <sup>241</sup>Am.

end of institutional control are most sensitive to the Soil Site eters affecting the dose from agricultural pathways. A 50 years, the to the transuranic radionuclide concentration of HORNET GZ soil vegetable intake produced in the home garden. By 1,000 years, the CA the transuranic soil concentration at the HORNET GZ, and the fraction 1 on site.

r uncertainty on CA results was investigated using Monte Carlo tainty analysis indicates that there is a very high probability that the 30 mrem/yr options analysis limit. The maximum TEDE obtained by m was 8 mrem/yr at 250 years.

I on many assumptions. Important CA assumptions are that ill be maintained for 250 years, that no remediation of contaminated hat exposure will be through a residential scenario, and that access to estricted in perpetuity. Doses may increase if the institutional control years, but there appears to be a high probability that the TEDE from closure will be less than the 30 mrem/yr dose constraint. The land use in the assumption that no remediation will occur are very conservative. Trainty in future land use and final remediation of Yucca Flat, the CA we bounding case. More probable assumptions will only lead to lower

# st Site

Nye n)

h the ished h -site IS . It site and bosal it entally

(PA)

neet urce evel

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h a

ses CA

o man resulting from the DE (1988a). CAs assess the I, from the facility being I in DOE (1996a). These in Section 1.5.

ner 1996, Interim Format nt of Energy Low-Level , requires that this guidance Therefore, the scope and the

ical analysis and f the report are included in g specific technical details ment readability. A

rea 3 RWMS, and isposal facility and site, the

ristics of the Area 3 RWMS ics of the site which stable environment and/or nmental transport media. one (unsaturated zone)
2 discusses data quality ctive contaminants conscriptions of facility design the other sources of radio-

ncluded in this chapter are

eir development, along with application of the models, leters treated deterministically, and probability distribud stochastically, are included in the appendices. The include Appendix 2, Estimation of Inventory at tual Model Development; Appendix 4, Release and osite Analysis and Air Transport Modeling; and Method.

ne analyses performed for PA and CA, including analyses. The results are summarized for the all-thway analysis, the radon flux density, the "protection the "as low as reasonably achievable" (ALARA) ruder analysis, and the composite analysis.

valuation. The PA/CA results are compared to the nethods by which PA results impact waste acceptance in the characterization are included in this chapter. hapter 5.

e issues associated with the work performed to support

nents for the key preparers of the PA and the CA, and

ons for references cited in the previous chapters.

ing the data and analyses presented in the above

ogeologic characterization of the vadose zone vicinity. It also presents the results of a modeling arge to the groundwater from a low-frequency precipiadionuclides from the facility to the groundwater are

imating the inventory at closure from disposal records, y and sensitivity.

of the site conceptual models, both hydrologic and

1 transport models used in the PA. Included are the oped for estimation of:

lides.

S

by which the probability of inadvertent human intrusion he mechanism of water well drilling (depth of burial much less likely), in the Area 3 RWMS was estimated. The straight of Black et al. (2000). In Black et al. (2000) appear opinions of experts in a variety of disciplines, which bility of inadvertent human intrusion occurring at the ace period.

results, including the screening of the pathways, and the or the CA.

sments performed using pathway dose conversion factors

my Air Field 1951, Frenchman and Yucca Flats were ommission, a predecessor of the DOE, for use as the testing site. Jackass Flats was added to the site in 1958 as ment Station (Beatley, 1976). In 1964, Pahute Mesa was ice testing (Beatley, 1976). The locations of Jackass Flats, e Area 3 RWMS are depicted in Figure 1.2.

oproximately 3,560 square kilometers (km²) (1,375 square of the state of Rhode Island. The NTS is surrounded and nd west by the Nellis Air Force Range (NAFR). This is rea, inaccessible to the public.

acca Flat, approximately 120 km (75 mi) northwest of Lasters (m) (3,920 feet [ft]). Average daily maximum and lat are 11 degrees centigrade (°C) and -6°C (51 degrees ary and 36°C and 14°C (96°F and 57°F) in July (DOE, on across Yucca Flat ranges from 50 to 350 millimeters tential evapotranspiration (PET) far exceeds precipitation. Area 3 RWMS was 1625 mm (64 in.).

#### Nevada Test Site

and U-3bh (depicted in inder RCRA interim 1988, waste in U-3ax/bl isidered in CA calcu-

bulk radioactive waste. PA and CA

osal area; these have uld waste be disposed vision or addendum to

l operational period of oughout this period, the

ing the period of active cause of the presence of ing and other effects of likely to occur within ow long institutional as in societal priorities, propological, and tribution on this length ch is also its mode, is

g this period, the land is ostinstitutional control

ig the postinstitutional ectives to be met during aling with the IHI are as directed by

.1 through 1.5.5. mpliance boundary,

ap performance. Complete descriptions appear in the

#### riod

the NTS is assumed to be 250 years in length. Black *et al.* tion on the length of the period of institutional control. node of this distribution (the two are equal for the fitted is provided in Appendix 5.

d for both the PA and the CA is 1,000 years, as indicated alculated to 10,000 years. Doses occurring beyond the ot considered for compliance; these doses are calculated ncrease understanding of the Area 3 RWMS likely long-

and CA are given in Table 12, 1.3, and 1.4. CA y defined in light of probable future land use (DOE, ated that similar boundaries, based on probable future land ntly, there are no plans to release Yucca Flat from governuture land use indicates that Yucca Flat will continue to be sible to the public. Further discussion of the land use Section 2.2 Data Quality Objectives. Black et al. (2000) for a community to arise somewhere on the land that is ontrol period. Under this scenario and the assumption that ess, persons wishing to live near but not actually in this le in Frenchman Flat or, less plausibly, Yucca Flat because cause persons residing in Yucca Flat during the postinstissible, although unlikely, the compliance boundaries for be 100 m (330 ft) from the edge of the RWMS. If no a compliance boundary 100 m (330 ft) from the edge of the he PA and CA.

#### Processes, and Events

facility (site stability, waste isolation) is modeled assuming agic and hydrogeologic) which would adversely impact the ur. Climate is assumed to remain constant throughout the ough variations within the bounds of historic activity are

## jineered Closure Cap

l be a single thick layer (monolith) of native alluvium. No ny engineered barrier to enhance overall facility perforthe alluvium placed over the waste in the disposal cells. d of the institutional control period, the closure cap Itaneous. The subsided unit geometry is assumed to match that described in for the duration of the compliance period. The subsidence unit will allow recipitation and runoff from the tributary drainage area, to occur.

#### ties of PAs and CAs

	PA	CA
onsidered:	1,000-year compliance period; doses calculated beyond the compliance period for informational purposes	1,000-year assessment period; no requirement beyond 1,000 years
aste nsidered	All waste disposed in the RWMS on or after September 26, 1988	All sources interacting with the RWMS
eracting urces	Waste disposal site only	All
mber of blic (MOP)	100 m from the boundary of the RWMS	Assumed to reside as close to RWMS as plausible patterns of future land use will allow
idvertent man Intruder	Considered	Not considered
	Complex, relatively realistic	Relatively simple, screening

## ary of Adopted PA Performance Objectives for the Postinstitutional Control Period

riod	Pathway	Compliance Point	Performance Objective
Control	All Pathways	100 m from the Area 3 RWMS Boundary	25 mrem/yr
	Atmospheric Pathway (excluding radon)	100 m from the Area 3 RWMS Boundary	10 mrem/yr
	Radon Flux Density	Waste Cell Cap	20 pCi/ m <sup>2</sup> /s
	Groundwater	Uppermost Alluvial Aquifer	Meet state of Nevada Drinking Water Standards

Table 1.3 Summary of Adopted PA Performance Objectives for Inadvertent Human Intruders

Compliance Interval	Pathway	Exposure M	Iode Performance Objective
Position to the second		Acute	500 mrem
Postinstitutional control	All pathways	Chronic	100 mrem/yr

Table 1.4 Summary of Adopted Objectives for CA

Compliance Interval	Compliance Point	Pathway	Performance Objective
Pre- and postinstitutional control	100 m from the Area 3 RWMS Boundary	All pathways	100 mrem/yr

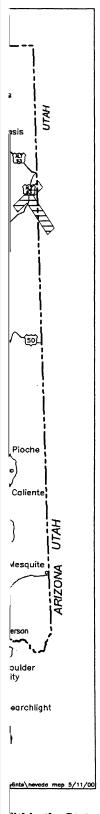




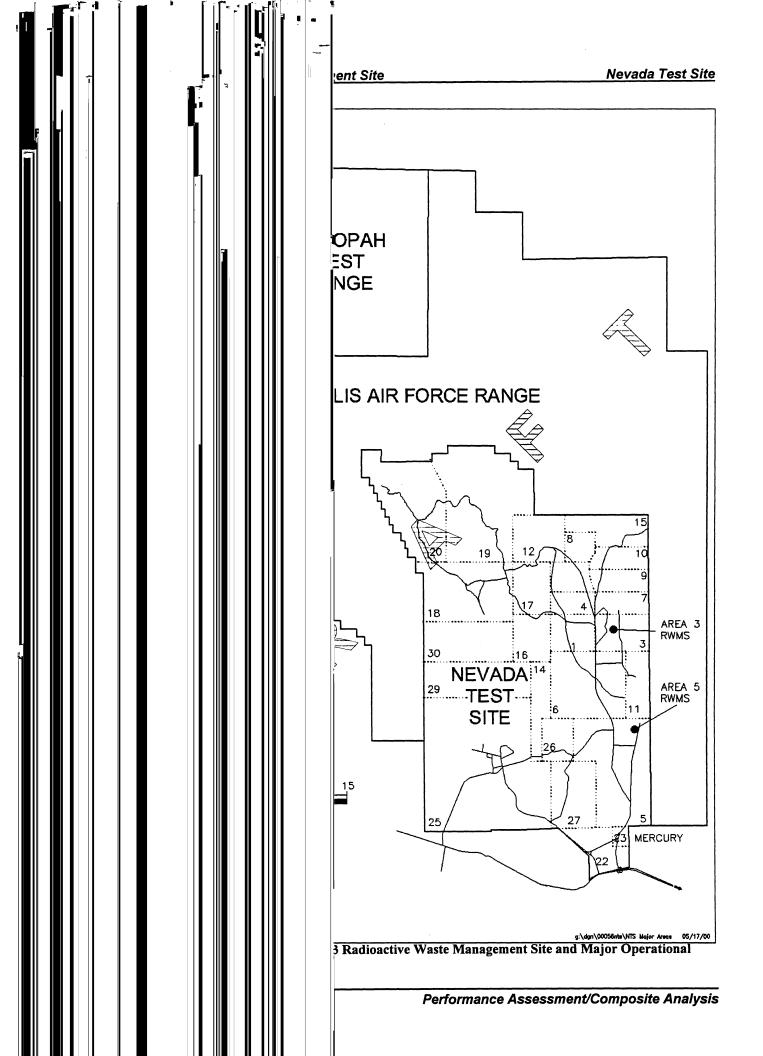




## Nevada Test Site



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nagement Site

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### RISTICS

hic Province. The Basin and Range is a mountain ranges. Alluvium-filled emselves result from down-to-the-basin generally coincides with the northern inor discrepancies exist (Figure 2.1). In internal drainage; no streams or rivers

Natural topography has been altered od control structures, various excavand southern part of the NTS is characranges (Figure 2.2). Topography of the canic highlands of Pahute and Rainier lat, Frenchman Flat, and Jackass Flats. I; each contains playas. Jackass Flats 1. Elevations at the NTS range from s Flats to about 2,340 m (7,675 ft) on Mesa.

t of Area 3, ranges from approximately t the playa in the south. The elevation ce craters resulting from underground of Yucca Flat. Within the Area 3 reation of waste disposal cells.

the contiguous 48 states. In 1990, the s per km² (10.8 persons per mi²). This n² (72.5 persons per mi²) for the con-DC], 1990). Permanent settlement in adily available or economically signifor shallow water resources are rare, readily available water. The intervening a indicate that Nevada's population is and Las Vegas. A map of Nevada Figure 2.3. At the 1990 census, urban ercent of the population (DOC, 1990) an *et al.*, 1993). Most of the remaining

00. The population ersons per mi<sup>2</sup>) (DOC, only 0.3 percent of

as lies approximately
ni) southeast of the
accounting for
/alley, the nearest rural
ly 57 km (35 mi) southy rural population

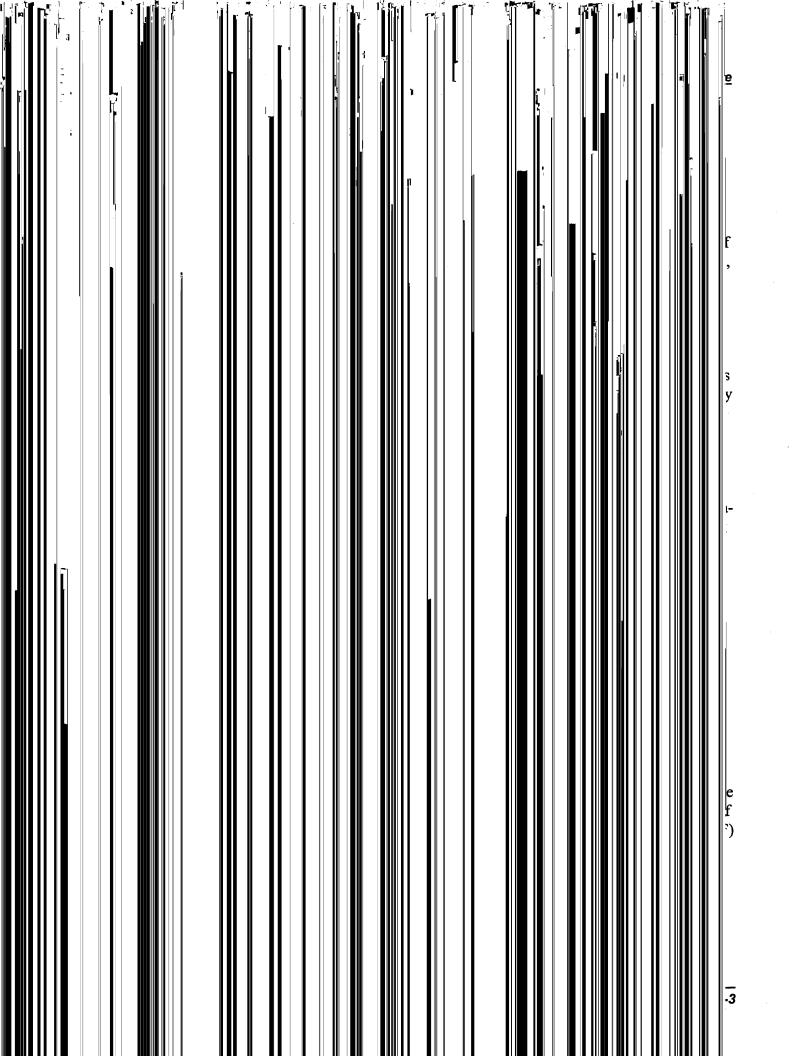
The Shoshone lived at TS were used by the d wild horse capture gin of Frenchman Flat e NTS in the Oak 5). In 1928, Cane Allred et al., 1963). levada. Recreational tant land uses in ourred rapid develop-

land laws in 1940. ewing the land ignated as a Nuclear ur within this region in

ortunities. Constraints uture activities. At the lent, unstable soils, and that can be accomnts are discussed in the nvironmental Impact of Nevada (DOE,

and the southern limits tional Desert.

nent/Composite Analysis



#### Nevada Test Site

on 1,225 m inimum air

ke meteorology ! m/s (7.2 mph). The

s are northerly. Wind ear in Figure 2.8. verages of daily IS meteorology eight of 9.5 m (31 ft), e 2.9). Wind speeds

T is defined as and from a variety of enbos and Pruitt, rea 3 RWMS and 2.10). Compare this IS meteorology cipitation was gure 2.10 is called his region indicates y in a moisture

nment is via the 113 = 14.4, indicating

g contamination to piring infiltrating oils generally limit support sparse

ies: the Mojave sert community,

nt/Composite Analysis

interspersed Transitional Desert community (Beatley, 'ithin each regional community, local communities are numerically dominant and co-dominant perennial ell and Emery, 1976). Local communities grade and climatic conditions change, resulting in a complex no two locations having identical species compositions

er the southern third of the NTS, on the piedmont and ,200 m (3,940 ft). Mojave Desert communities have at all share a shrub clump form dominated by creosote co-dominant shrubs (Beatley, 1976).

r under two conditions: along elevation gradients in Desert communities, and at the bottoms of closed ring the night (Beatley, 1976). These communities are ve or Great Basin Desert communities. On the NTS, vne and Larrea-Grayia Lycium, occur along elevation piave Desert communities. Blackbrush (Coleogyne nds on upper-elevation piedmonts, beyond the moisture (Beatley, 1976). Larrea-Grayia-Lycium assemblages w Coleogyne communities (Beatley, 1976). Three ium, Lycium pallidum-Grayia, and Lycium shockleyielevations of closed basins (Beatley, 1974; 1976). exture and salinity, as well as nighttime temperatures, nunities.

r within basins and on mountains at elevations above ry, 1976), having lower temperatures and greater Mojave Desert communities (Beatley, 1976). In nities, Great Basin Desert communities tend to have nuals, and shrub clumps tend to be compact or absent are dominated by either Atriplex spp. (shadscale [A. canescens]) or Artemisia spp. (big sagebrush nova]) (Beatley, 1976). Above 1,800 m (5,900 ft), nophylla)-juniper (Juniperus osteosperma) associations

dominately Transitional Desert communities, although a resent (Figure 2.11). Plant communities near the nunities dominated by desert thorn (*Lycium andersonii*), winterfat (*Ceratoides lanata*), fourwing saltbush, and rata) (Hunter, 1992; Winkel et al., 1995). Plant considered to be similar to the *Lycium-Grayia* or nkel et al., 1995).

Analysis 2-5

ed the rooting depths of Mojave Desert or Transitional Desert studies have found that plant roots in NTS desert communities are urface. This is likely an adaptation to maximize the capture of l., 1995). Wallace and Romney (1972) described the root systems d from a wash in Rock Valley on the NTS and reported a maximum (cm) (66 in.) for creosote bush, which currently does not occur at deepest rooting plant occurring at the site, had a rooting depth of orted maximum root depth for individual plants appears in (1980) excavated the root systems of several Mojave Desert species the roots to be distributed in the top 50 cm (20 in.), except for adscale. Less than 2 percent of the roots of these species were found atley (1969) reported that winter annuals root in the top 20 cm (1984) surveyed the rooting depths of plants at a site in New nean rooting depth reported for species that occur at the Area 3 ly 400 cm (160 in.) for fourwing saltbush. They report that for three cent or more of the specimens rooted at depths less than 457 cm

is low in these desert communities. Winter annual standing s the production of a single growing season, can vary from 0 to alue of 90 kg ha<sup>-1</sup> has been recorded for the NTS (Beatley, 1969). 72) found that perennial shrubs produced the greatest biomass in year study period. Their estimates of primary productivity as the standard deviation were  $190 \pm 100$  kg ha<sup>-1</sup> yr<sup>-1</sup> for annuals,  $407 \pm 100$  kg ha<sup>-1</sup> yr<sup>-1</sup> total. Over two consecutive years, norted aboveground net primary productivity of perennials in Rock and 436 kg ha<sup>-1</sup>.

a significant fraction of standing biomass and net primary of herbivory are generally low in desert environments, suggesting of plant biomass becomes soil detritus each year (Strojan *et al.*, '9) estimated that dry litter fall from perennial shrubs in Rock terval was  $217 \pm 141$  kg ha<sup>-1</sup> yr<sup>-1</sup>. Total dry litter fall, including be  $362 \pm 237$  kg ha<sup>-1</sup> yr<sup>-1</sup> (Strojan *et al.*, 1979). Annual litter fall boveground biomass among perennial species ranged from 7 to 1979). Annual litter fall was estimated to be from 81 to 99 percent activity (Strojan *et al.*, 1979).

nial plants appear to be capable of rooting directly in waste. The annual root biomass is expected in the upper 50 to 100 cm (20 to

## a Test Site

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densities and habits of larger vertebrates on the NTS. mmonly observed on the NTS are black-tailed al's cottontail (Sylvilagus nuttalii), kit fox (Vulpes). The Nuttal's cottontail, kit fox, and coyote are brate species are very rarely observed. Badgers becies, occur on the NTS but are rarely seen. Large game e mountain lion (Felis concolor), bobcat (Lynx rufus), ronghorn antelope (Antilocapra americana), and desert hese species, living at higher elevations, are rare

tative predictions of the effects of burrowing fauna on tity of soil transported to the surface depends on popud seasonal activity levels. The transport processes are ket gophers, are reported to selectively transport cobbles and Morris, 1968; Hakonson et al., 1982). Burrows are sumably with both clean and contaminated material, ice soils (Thorne and Andersen, 1990). Burrowing ion (Voslamber and Veen, 1985; Thorne and Andersen,

ct site performance by burrowing into waste cells and face. Direct intrusion into waste by mammals appears by burrow to shallow depths. Anderson and Allred microps) burrows on the NTS. They reported a 4 in.) and a mean depth of 33 cm (13 in.). Burrowing of the soil (Anderson and Allred, 1964). Winkel et al. burrow depth of 175 and 98 cm (69 and 39 in.) for i). Winsor and Whicker (1980) found that the pocket (12 in.), and its average burrow depth on their Colorado conson et al. (1982) recorded the depths of southern a LLW site in northern New Mexico. None of the 9 in.). Winkel et al. (1995) reported that southern p as 160 cm (63 in.). The kit fox appears to be the only into waste. Its maximum burrow depth has been kel et al., 1995).

imals occur within Yucca Flat; their activities may strusion into buried waste by vertebrates is judged p enough to reach waste. However, they are unlikely to pulation density of 0.02 to 0.001 per hectare (ha) (0.004 l., 1995). Most vertebrate burrowing appears to be

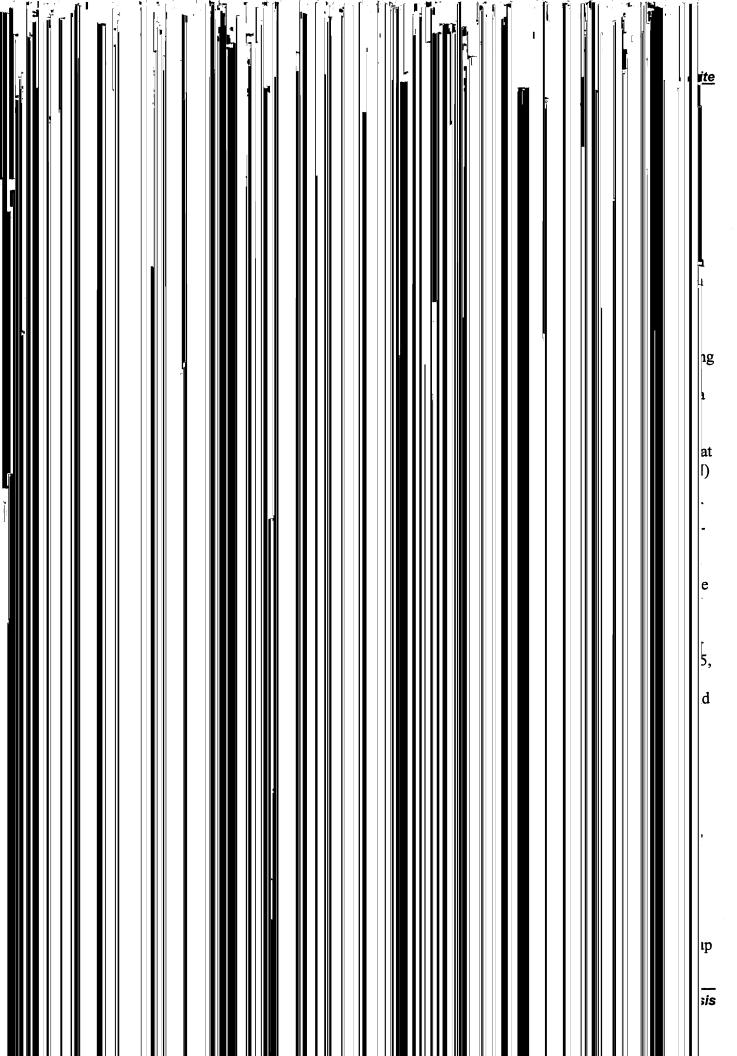
## vada Test Site

e burrowing hydraulic environment f the

marily origin, made 78). These on. In the ruded by sedimentary Era. This ing in the Volcanic Province thwest deras. These . Volcanic ion of the rnary, volcanism.

Range at least two sisted of st-11 Ma, rlier phase is ach maps of ne Mountains faults rely filled the

n² (300 mi²). 0 m (4,600 ft) at an eleva-Yucca Flat is ne east, the Mountain and nentary rocks



this tuff formation, where it is present, les in Yucca Flat were drilled beyond the refore, only limited data are available to

lled within Yucca Flat, is the closest of the Area 3 RWMS. The stratigraphy of 1 U-3cn#5, 282 m (930 ft) of alluvium is Rainier Mesa Tuffs, which make up the oup is underlain by an additional 787 m are often difficult to distinguish in tuff I during borehole logging: the Wahmonie m [1,430 ft] depth), Tunnel Formation m [2,102 ft] depth), Tuff of Twin Peak vium (818 m [2,685 ft] depth) (Drellack ft), the top of the Paleozoic section of 224 m

an the alluvium within the Area 3 RWMS, nsively characterized. Seven boreholes RWMS (Figure 2.15). Two boreholes to the collapse zone of crater U-3bh, two a 45-degree angle under crater U-3bl and is drilled at a 45-degree angle away from n, and two boreholes (U-3at-D1 and U-1 U-3at and into the collapse zone. The typical of alluvial valleys on the NTS.

ypical of the Basin and Range of Tertiary volcanic rocks overlying th sides of the basin. These ranges bound raphy in the basins. Erosion of the ranges position of a significant thickness of realluvial surface and ongoing structural sent alluvium thicknesses. Mid-basin lly range from 30 to over 700 m (100 to ck, 1994).

rocks at the NTS is very complex. Pre-Mesozoic time (the Sevier Orogeny). In leozoic section are repeated as a result of Mesozoic thrust faulting. Most thrust plates at the NTS were transported eastward with displacements on the order of 10 km (6 mi) (Orkild, 1983). In Miocene to Quaternary times, these Paleozoic rocks and the overlying volcanic units were disrupted by large-scale extensional block-faulting, the primary cause of the present Basin and Range topography.

Bechtel Nevada (1996b) has produced a west-east cross section showing the structural setting of Yucca Flat. Some of the faults identified in BN (1996b) can be projected to the surface and correlated with crack trends on composite postshot surface effects maps (U.S. Geological Survey [USGS], 1990). Many of these "younger" faults (e.g., Yucca Fault) displace features such as the tops of zeolitization (Drellack, 1995) or internal bedding within the deeper alluvium (Elwood *et al.*, 1985). Other faults, considered "older," are not readily discernable on either surface effects maps or the top of zeolitization contour maps. Most of the displacement on these faults is dip-slip. However, a right-lateral strike-slip component of motion has been documented (Ferguson, 1981). Vertical displacement on these normal faults ranges from approximately 610 m (2,000 ft) on the main basin-forming faults, to less than 15 m (50 ft) on the lesser faults.

The principle basin-forming faults in Yucca Flat are the Yucca and Carpetbag Faults, both east-dipping, moderately high-angle normal faults (Figure 2.13). The Yucca Fault is located in the east-central portion of the basin, trending north-south and extending through the valley. The Carpetbag Fault, also striking north-south, is located in the western part of the valley. Toward the south, the Carpetbag Fault steps eastward in an en echelon fashion, becoming the Topgallant Fault. The Carpetbag Fault represents the eastern side of a large north/south-trending buried horst of Paleozoic carbonate rocks also referred to as the "Gravity High"). This horst separates the large main basin on the east from several smaller subbasins on the west.

Age estimates for these youngest faults have appeared in several studies (Knauss, 1981; Shroba et al., 1988). Knauss (1981) brackets the age of the last natural movement along the Carpetbag Fault between 37 and 93 ka and along the Yucca Fault at less than 35 ka.

The Area 3 RWMS is located on a structural block that is bounded on the east by the west-dipping Area 3 Fault and on the west by the east-dipping Yucca Fault. The nearest known fault to the Area 3 RWMS passes through the eastern margin of the facility and is called the Area 3 Fault. The projected surface trace of this fault is assumed to follow a minor, but persistent, trend of postshot surface fractures. It is unclear if the Area 3 Fault is an actual tectonic feature reactivated by underground nuclear testing, or if it is purely a shot-induced feature. Bechtel Nevada (1996b) undertook a literature review to determine when the Area 3 Fault was first described and how historical reports have considered the feature. In addition, trenches were excavated that cross the trend of the Area 3 Fault to determine if tectonic movement is discernable in the shallow subsurface.

The Area 3 Fault was first named and mapped by Williams *et al.* (1963) as a zone of surface cracking caused by the BILBY and BANDICOOT events. Some of the fractures showed up to 15 cm (6 in.) of offset. The predominant sense of motion for fractures with offset was

et al., 1963; Williams, 1964). A study of 1951 d no pretesting lineaments along the Area 3 Fault east of emplacement hole U-7b near the northern (1965) mapped a 3,660-m- (12,000-ft)-long ortened and transferred to a surface effects comthey called this lineament the East Branch Area 3 s in Pleistocene alluvium have been noted on the

a 3 Fault has not been found. However, a gravity ) at the north end of the Area 3 Fault. This might of the northern projections of the fault. If so, it of the Paleozoic surface to the east. However, the , closely spaced faults in the area, as shown by lence of the subsurface nature of the Area 3 Fault fault is likely to be minor in comparison with the

a zone of aligned fractures and small scarps ree possible prehistoric scarps have been excavated across two of these scarps.

ted within the Great Basin, a closed hydrographic e NTS are subbasins of the Great Basin. Streams response to precipitation events or snowmelt. he bottom of the closed hydrographic basins, NTS: Frenchman and Yucca Lakes. These lie in igure 2.16). While water may stand for a few playas are dry most of the year.

mial surface water in the region. There are nine ter discharged from springs travels only a short or infiltrating into the ground. The only other ts constructed for operations. These are voirs, containment ponds, and sewage lagoons. known to occur on the NTS.

RWMS, located within the 780 km<sup>2</sup> (300 mi<sup>2</sup>) of coalescing alluvial fans issuing from the 1 the alluvial fans convey runoff to Yucca Lake, the Area 3 RWMS. Five of the nine springs on

s 2-13

ted approximately 6 km cility. The nearest conximately 0.2 km (0.1 mi)

pnducted for the Area 3 thin a 100-year flood Agency (FEMA). Further, f flood protection.

rial photographs of Yucca rectly impact the Area 3 Ilfpint Range, including ckeyed Ridge, and Banded nanating from these

S could occur as alluvial fan and sheetflow flood drologic and hydraulic ty.

100-year flood depth n an alluvial fan designated epth with flow at the desigside the 100-year flood ese areas, average depths are essible flooding, flood entrol.

Area 3 RWMS were ons were used to denote the itside the FEMA-designated Paiute Ridge alluvial fans. nerefore, the Area 3 RWMS v.

d in a number of studies; and Blankennagel and ccurate characterization of data (few wells penetrate ects caused by nuclear omplexity of the hydromplete and recent summary

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A Yucca Flat lies within the Ash Meadows groundwater subbasin. aquifer within this subbasin is the only subsurface pathway by the Yucca Flat basin. Groundwater flows south from Yucca Flat nen southwest toward downgradient areas (primarily Ash tflows are small because inflows to Yucca Flat are limited by he basin. The total inflow to the lower carbonate-rock aquifer ateral sources is estimated to be about 300,000 m³/yr (250 acreercent of the total 430,000 m³/yr (350 acre-ft/yr) inflow to the lower leath Yucca Flat calculated by Winograd and Thordarson (1975). heath Yucca Flat of 430,000 m³/yr (350 acre-ft/yr) comprises less outflow at the Ash Meadows discharge area, estimated to be about cre-ft/yr) (Winograd and Thordarson, 1975).

wer carbonate-rock aquifer indicate that the gradient is nearly flat ni]) between Yucca and Frenchman Flats and down to the disws. This flat gradient is an indication of a high degree of hydraulic er, which is probably a result of a high fracture (secondary) uity does not necessarily imply uniformity of flow properties. Eath the NTS passes through a complex geologic framework whose numerous factors including stratigraphic age, lithologic 1 geometry (Laczniak et al., 1996).

neralized hydrogeological cross section in Yucca Flat. The ring the lower carbonate rock aquifer are thought to consist of quifer and confining units). The alluvium unit is variably cemented sorted deposits of gravel and sand having high interstitial porosity aquifer is a welded tuff and is characterized by high fracture nts of saturated hydraulic conductivity of seven welded tuff to 771m/day (0.30 to 5.61 ft/day) (Rehfeldt et al., 1995). The tuff ized as a bedded, nonwelded tuff that has been altered to zeolite volcanic reactions with groundwater, resulting in decreased rock nts of saturated hydraulic conductivity of 34 zeolitized tuff to 0.02 m/day (7e-6 to 0.07 ft/day) (Winograd and Thordarson, ng unit is present only in the western part of Yucca Flat and does 3 RWMS.

eptualizations of the regional groundwater flow systems and ystems are believed to be somewhat understood for the NTS (with basin boundary locations, and lateral flow into and across subsystems at smaller scales are poorly understood. The mechanical iderground testing on the local groundwater flow system beneath inknown, although groundwater mounding and fracturing are of testing. In addition, chemical reactions between groundwater

#### Nevada Test Site

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based on drillhole U-3ah and U-3bg pundaries of the nole that penebrth of the RWMS. ick and the top of and 670 m (1,440 1,614 ft) below

Plate 1 included ogy Report, County, Nevada." of the facility and are-contour maps.

ortion of the Area 3 the lack of deep trated the Tertiary est sides of the

a Flat laterally, urated units. Conrock aquifer are k. The leakage tuff confining unit, e tuff confining by Winograd and a the confining

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e (1975) of between quakes of ake on the All historical earthquakes within Yucca Flat had magnitudes below 3.0. The largest earthquake recorded on the NTS (magnitude 5.6) occurred at Little Skull Mountain, approximately 40 km (25 mi) southwest of the Area 3 RWMS, on June 29, 1992. In August 1971, a magnitude 4.3 earthquake occurred along the Cane Spring fault, approximately 15 m (9.5 mi) south of the RWMS. These earthquakes caused no surface displacement.

The Area 3 RWMS makes limited use of engineered structures, making the site less vulnerable to earthquake damage than an aboveground facility or a facility using engineered belowground vaults. Barring a major earthquake centered on the Area 3 RWMS, only limited compaction, caused by the consolidation of alluvium, might be expected. Large events have large return times. Events are highly unlikely to be centered on the Area 3 RWMS. Together, these issues make it highly improbable that seismic activity will compromise the integrity of the RWMS.

#### 2.1.6.2 Volcanism

No post-Miocene silicic volcanic centers are present in the southwest Nevada volcanic field, a large volcanic field that covers a region encompassing the NTS (Byers et al., 1989; Sawyer et al., 1994). The only silicic volcanic centers of Pliocene age or younger within a 100-km radius (62 mi) of the Area 3 RWMS are located in the Mount Jackson area southwest of Goldfield, and in the Funeral Mountains of southwest Death Valley (Crowe et al., 1995). The hazards of future silicic volcanism for the NTS region are negligible (Crowe et al., 1995; Geomatrix, 1996). There has been no silicic volcanism in the NTS region for the last 8.5 Ma.

Post-Miocene basaltic volcanism in the NTS region is divided into two episodes (Crowe, 1990): (1) large-volume basaltic volcanic centers that are spatially and temporally associated with the waning phase of silicic volcanism (basalt of the silicic episode); and (2) small-volume, spatially scattered basalt centers that postdate silicic volcanism (post-caldera basalt). The latter episode of basaltic volcanism is subdivided into two cycles, including late Miocene basalt centers that occur in the east and north-center of the NTS; and Pliocene and Quaternary basalt centers that occur mostly in the southwest part of the NTS region with one 3.0 Ma center (basalt of Buckboard Mesa) present in the northeast part of the Timber Mountain caldera (Crowe et al., 1995). The youngest basaltic volcanic center in the NTS region is the 0.07 Ma basalt of Lathrop Wells, located approximately 5 km (3 mi) south of the southwest corner of the NTS (Crowe et al., 1997).

There are no post-Miocene basaltic volcanic centers in the vicinity of the Area 3 RWMS. The youngest basalt within Yucca Flat is the basalt of Yucca Flat (8.1 Ma), found at a depth of 226 to 308 m (740 to 1,010 ft) in drillhole UE1h, located about 1.5 km (1 mi) southwest of the Area 3 RWMS (Marvin et al., 1989). The closest basalt centers exposed at the surface near the Area 3 RWMS are the basalt of Paiute Ridge (8.6 Ma), located approximately 6 km (4 mi) northeast of the Area 3 RWMS (Ratcliff et al., 1994); and the basalt of Nye Canyon (7.3 to 7.4 Ma), located approximately 19 km (12 mi) southeast of the Area 3 RWMS (Crowe et al. 1997). A probabilistic assessment of the hazards of future basaltic volcanism (probabilistic volcanic hazard assessment) has been conducted for the Yucca Mountain site, an area

ground storage of high-level radioactive waste (Crowe et al., 5); these assessments can be applied indirectly to the Area 3 st hazard for future basaltic volcanism in the NTS region are in ıral zones of Pliocene and Quaternary basaltic volcanism acca Mountain site is located outside of, but adjacent to, zones of altic volcanism. The probability of future magmatic disruption ie Yucca Mountain site (3 km² [1 mi²]) is about 1 to 2e-8 per omatrix, 1996). The probability of magmatic disruption of an de of Pliocene and Quaternary volcanic zones is less than about 997). The Area 3 RWMS is located outside of, and at a Il Pliocene and Quaternary volcanic zones and the probability of f the Area 3 RWMS must be less than or equal to this proba-'ility of magmatic disruption of the Area 3 RWMS is approxiir compliance period of a disposal site for low-level radioactive fficiently low that basaltic volcanism can be dismissed as a event for the Area 3 RWMS.

#### Resources

eologic resources are identified for NTS: sand and gravel, eum. A resource is not economically viable unless it is available tity and a demand exists. Limited quality, quantity, and/or commercial exploitation of geologic resources in the NTS

#### el Resources

an alluvial fan. This suggests that sand and gravel might exist a viable resource. Trenching and borehole logging show that sediments are present in discontinuous beds. In general, these ne gravel, with minor silt and clay. These minerals are present bably be viable resources. However, the gravels and sands are nic rocks, with lesser amounts of carbonate and siliciclastic inant pyroclastic rocks are friable and thus poorly suited for

for road base, building pads, and other fill structures. sand and gravel depends on infrastructure and development. Alamo, Beatty, and Pahrump Townships) are relatively small, the Area 3 RWMS. Sand and gravel resources, adequate for the plation centers, are available much nearer the centers than the

ends on site activity (Richard-Haggard, 1983). NTS population Demand for sand and gravel, of sufficient quantity to impact most certainly have to originate from activity in Area 3. No peration of the Area 3 RWMS, are currently planned for Area 3.

entified on NTS (Figure 2.23): Calico Hills, Wahmonie, Dak Spring, to the far north end of the basin, and Mine the basin, lie within Yucca Flat. The Wahmonie and Calico rest of Yucca Flat, respectively.

pring District. Potentially economic mineral deposits may Commercial tungsten mining occurred in the Oak Spring arly 1960s. Hence, the NTS region is considered to have ce of tungsten skarn deposits (Science Applications esearch Institute [SAIC/DRI], 1991). Molybdenum is M, 1979). Iron is present; however, the resource potential lost volcanic rocks and alluvial basins in the NTS region. Ite deposits in the region suggests a low to moderate occurs in veins associated with quartz and mercury, Barite veins at the NTS are small and impure; they are barite resource. Although fluorite is present in the e occurrence. However, its resource potential is thought

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1991).

s is low in southern Nye County (Garside et al., 1988; resents simplified views of this potential, based on source t and Carlson, 1978; Harris et al., 1980) and reported a shows. Studies in southern Nye County and the NTS 1, tar sand, nor oil shale. However, a recent evaluation of ts a "cautiously optimistic view of the hydrocarbon potence (Trexler et al., 1996). Trexler et al. (1996) found that yide potential reservoir spaces and that the thermal history ydrocarbon.

as been limited. Prior to 1953, when the Nevada Oil and screated, information concerning drilling is incomplete. sh November 1992, approximately 650 hydrocarbon wells nighest concentration of these wells is in the Railroad runty (*Figure 2.24*).

discovered in Railroad Valley. Productive areas of these bre than 10.4 km² (less than 1.0 to more than 4.0 mi²). approximately 1,220 to 2,130 m (4,000 to 7,000 ft) ion from these fields is found in structural traps or a phic traps. Producing formations include Paleozoic is Tertiary volcanics. The only oil production in Nevada lackburn Field. The Blackburn Field, discovered in 1982,

i) north of Railroad Valley in Pine Valley, Eureka County burn Field is from tuffs, tuffaceous sandstones, and ociated with a combination structural-stratigraphic traps lls have been drilled for oil and gas within a 50-mi (80-km) report hydrocarbon production (Garside et al., 1988;

ally acceptable for drinking water and industrial and one in groundwater quality arise from groundwater aczniak et al., 1996).

ency (EPA) groundwater classification guidelines plying drinking water to the NTS as Class II groundwater water is water that could be or is currently being used for

roundwater indicates that volcanic units contribute uifer (Table 2.3). The contribution of sodium and chloride alt from downward leakage or lateral flow from structurally and Lyles, 1993).

Flat to be utilized, certain conditions must be met (the nust be present sufficient quantity, and water quality conditions, water resources within Yucca Flat have at least rigation, commercial geothermal energy development, and

ertile soils, such as those of the NTS, restrict crop choice. ictices and management to effectively produce crops *l.*, 1984).

rerned by the Office of the State Engineer and the Division undwater management policy requires that total witheld; more often than not, overdraft occurs before yield is raints deter agricultural usage, although regulations could

mmercial geothermal energy development. Temperatures a Mountain range from 50° to 60°C (122° to 140°F). logy requires reservoir temperatures of at least 180°C irces are representative of the area, geothermal energy 88b). Any potential low-level applications could be the

using potential. The Las Vegas ation. Accordingly, future growth Possible sources of water include ources, importing from elsewhere

n<sup>3</sup> (235 acre-ft) of groundwater 978 consumption rates, they a for approximately 40 years.

sible because of cost. However, as eep carbonate aquifers may become nate aquifers might become ig wastewater (Hess and Mifflin, eventually be utilized.

iantity and quality of data required onmental Protection Agency ign environmental sampling he decisions to be made and the of the DQO process are:

plem to be studied. Review prior ent understanding to define the

the study will attempt to resolve,

ne information that needs to be aken to resolve the decision

e periods and spatial area to which data should be collected.

parameter of interest, specify the puts into a single statement that ternative actions.

Define the decision maker's ation of the consequences of ate is the probability of making an estimate the true state of nature.

ce Assessment/Composite Analysis

nation from the previous steps and generate lose the most resource-effective design that

med that new samples will not be collected ip between the input data (e.g., radionuclide diological dose) is poorly known, it is incertainty tolerable in the input data or to ly the first five steps of the DQO processes e Equivalent (TEDE) is estimated and the tive parameters and cost-effective identified if necessary. The DQO process ient of Energy/Nevada Operations Office gement, Environmental Restoration, and

#### **Process**

that have left residual radioactive material s now within the NTS boundary will receive dioactive material left behind by DOE tecontinuing operation of the Area 3 RWMS and safety of the public, considering all

#### sion

or waste management. Its purpose is to WMS poses an unreasonable risk to the eracting sources of residual contamination. rovided, the CA can be used to select cost-ull interacting sources of contamination lection and data analysis, implementation of riteria, and remediation of contamination.

#### ision

e the maximum dose is expected. Estimaces that may contribute to the dose. The on, and spatial distribution of individual at and surrounding areas that could impact a ant sources of residual contamination are y of the site, radiological field surveys, and al near-surface contamination have been roup (NAEG) and the Radionuclide

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Nevada Test Site (Black et al., conditions, and ed in this ıl Unit, Nevada ed by Oak Ridge zision 1. i Hązardous the Area 3 und describes re (DOE, 1993). S. It examines e policy of y the the FFACO are s where activities gories of these ogical contamiıd materials. ing sites and uclide source Soil Sites; all Industrial tonations which Ss assigned to listinct, and haracteristics ther CAUs are te Mesa : (3 CASs). omposite Analysis

s to define containment boundaries around each UGTA insafe for domestic and municipal use. The containment er year dose at a 50 percent confidence level within a the contaminant boundary will be a restricted area – undwater usage. A regional groundwater modeling has al basis for assessing flow paths from the CAUs (DOE, I process will refine the CAU boundaries through ecific data. The closure activities under UGTA will be , 1997a). The UGTA project has just begun characterizaording to the FFACO schedule, the UGTA program is to transport model to assess radionuclide migration and ca Flat by FY 2008. Therefore, this iteration of the CA will areas associated with the test sites in the Yucca Flat. here will be these restricted areas, defined by the conhed by the UGTA program, in Yucca Flat where public 10 years. In the next iteration of the CA under the CA nant boundaries will be identified. The sole effect of the analysis would then be to increase the CA TEDE m, assuming the receptor would be located near the

of surface and shallow subsurface soil contamination clear experiments or testing. The FFACO identified the

uding airburst, airdrop, balloon, rocket, surface, and tower

oduced no nuclear explosions, but created surface

ear devices were used to excavate large volumes of earth.

ed at surface and subsurface Soil Sites. Remedies for of hot spots, and those for subsurface sites will range from

CA. It will be conservatively assumed that no cleanup will

al monitoring and environmental surveillance on and off ine Radiological Environmental Monitoring Plan rough the DQO process and integrating all previous

#### Nevada Test Site

om DOE/NV, BN, oint Testing ng plans for air, E Orders 5400.1, reviewed

are published
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applicable DOE,
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nd the NTS
advoactivity from
active dose
as estimated to be
g data. Environuples, the source
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Pu concentration
-18 Ci/ml.

nal Environmental tate of Nevada ement alternatives: ions, Expanded sued in December bed by the agement activities inder the Waste 0200) (DOE, atement will sposal of LLW, implementation of 1998a). The land s within the Yucca ea under one under e. "Nuclear Test nic experiments and gh-Explosive Test and outdoor nt, and Testing ds within the

## da Test Site

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al CA is to determine if there is reasonable assurance that a 5 RWMS does not pose an unacceptable risk. If the mean, it will be concluded that the CA provides reasonable assurdo not pose an unacceptable risk. The remaining steps of the ture iterations of the CA

#### on of Contaminated Areas

tt the NTS resulted primarily from atmospheric testing of d safety experiments (1955-1992). Locations of atmospheric 2.25; locations of safety experiments are shown in

nated soil near the test ground zero (GZ) at a few sites shots have distributed plutonium particulates over surface :-surface cratering experiments dispersed radioactive rock and inderground tests inadvertently have vented radioactive

of atmospheric and underground tests, including cratering ITS Operational Areas. The total activity remaining on lated at 2,368 Ci. The total inventory of Soil Sites in Yucca

nducted aerial surveys, in situ spectrometry, and soil distribution of radionuclides (McArthur, 1991). Aerial array of helicopter-mounted NaI(Tl) scintillation detectors to tion. In situ spectrometry measurements were carried out at ed as contaminated. The in situ measurements were made ermanium detector suspended about 7.4 m (24 ft) above the sed to compute concentrations of radionuclides from the pulses reaching the detector. When peaks were not detected inated, inventories were assigned based on the measurement erestimates inventory in areas with little contamination. The nents were determined using a microwave ranging system.

ites of *in situ* measurements to determine the depth I to measure concentrations of radionuclides which do not

n the top 15 cm (5.9 in.) of soil were collected. At a few sites, ge crater produced as the result of a Plowshare Project nuclear explosives), six samples were collected from the top a spectrometry was used to determine the depth distribution.

st Site 1984. rs. al in 20.2A. ater. in J-3ah k ⁄at. 1 3 in be ich astes sed at n nits. posed evised re ally Only es nalysis

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. Approximately 60 percent of the activity and ed by the Waste Consolidation Project. Mound e National Laboratory, combined, contributed Fernald Environmental Management Project contributed ne. This waste was in the form of decontaminating and ad with low levels of uranium. Undifferentiated gross reent of the reported activity.

ie estimated total activity disposed through the end of is 90 percent <sup>3</sup>H, 3 percent <sup>137</sup>Cs, 3 percent <sup>90</sup>Sr, and intory of U-3ah/at at closure was projected to be 5 ft<sup>3</sup>) of waste (*Table 2.7*).

### J-3bh Disposal Unit

onuclides estimated for U-3bh at closure in 2013 is predominant radionuclides on an activity basis are <sup>3</sup>H (24 percent), <sup>240</sup>Pu (5 percent), <sup>241</sup>Am (4 percent), <sup>137</sup>Cs total volume of waste is estimated to be 1.1 × 10<sup>5</sup> m<sup>3</sup>. e of 1.7 × 10<sup>5</sup> m<sup>3</sup>, the facility design factor is estimated

incertainty in the estimated inventory. Obvious sources include:

ed by the generator, and by the generator, if the records, e waste, and e waste.

ry uncertainty are poor or nonexistent. Inventory ting simple conservative inventory bounds based on

nty in the activity and volume reported by generators.

ne NTS WAC that acceptable waste characterization accurate to within an order of magnitude of the correct ue concentration of wastes characterized by generators times the reported value. The inventory has been inty contributed by incomplete records (see iion of the revision method indicates that the assumed te value) is probably conservative for revisions also. for radionuclide inventories estimated by the revision he only inventory assumed to have an uncertainty less

### Nevada Test Site

bry of Pu isotopes and <sup>241</sup>Am in the by *in situ* gamma spectroscopy and prted to be 0.6 and 1.4 times the

e and Romney, 1972)

### Plant

dumosa

ea salsola

evadensis (Mormon tea)

dentata (Creosote Bush)

s lanata\_(winter fat)

idersonii-(desert thorn)

inosa

# Test Site

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Table 2.3 Contaminated Soils Areas Within Yucca Flat (McArthur, 1991)

			Area		Easting	Northing	Distand the R	
Area	Region	(mi²)	(ft²)	(m²)	(ft)	(ft)	(mi)	(m)
1	GALILEO	4.80	1.34e+08	1.24e+07	664588	838780	4.4	7005
	HORNET	5.70	1.59e+08	1.48e+07	673500	847000	3.3	5244
	S. Yucca	7.60	2.12e+08	1.97e+07	673500	834000	2.7	4364
	Unsurveyed	8.40	2.34e+08	2.18e+07	673500	830000	3.0	4771
2	WHITNEY	2.70	7.53e+07	6.99e+06	660103	869823	8.1	13032
	SHASTA	4.90	1.37e+08	1.27e+07	663323	866030	7.2	11515
	DIABLO	4.00	1.12e+08	1.04e+07	662634	874146	8.5	13625
	SEDAN	6.10	1.70e+08	1.58e+07	677375	876375	7,7	12392
3	HORNET	8.50	2.37e+08	2.20e+07	688500	837000	0.2	305
	S. Yucca	4.60	1.28e+08	1.19e+07	685500	823080	2.7	4286
	Unsurveyed	19.20	5.35e+08	4.97e+07	700560	839000	2.5	4027
4	KEPLER	9.70	2.70e+08	2.51e+07	664462	854233	5.4	8769
	QUAY	5.20	1.45e+08	1.35e+07	675000	<i>\$</i> 53000	3.8	6189
	Unsurveyed	1.10	3.07e+07	2.85e+06	654140	<b>8</b> 54000	7.1	11412
7	QUAY	6.70	1.87e+08	1.74e+07	687500	851000	2.7	4267
	Unsurveyed	12.60	3.51e+08	3.26e+07	696030	853000	3.4	5527
8	BANEBERRY	5.20	1.45e+08	1.35e+07	665000	882500	9.6	15471
	SMOKY	3.30	9.20e+07	8.55e+06	674250	887750	9.9	15987
	Unsurveyed	5.40	1.51e+08	1.40€±07	<del>674250</del>	898330	11.9	19125
9	WILSON	7.50	2.09e+08	1.94e <del>(</del> 0.7	682500	869000	6.1	9872
	Unsurveyed	12.50	3.48e+08	3.24e+07	693060	869000	6.2	9900
10	SEDAN	7.70	2.15e+08	1.99e+07	681000	884000	9.0	14462
	Unsurveyed	12.30	3.43e+08	3.19e+07	691560	884000	8.9	14379
15	Yucca Flat	4.30	1,20e+08	1.11e+07	684500	894350	10.9	17504
17	Yucca Flat	11.20	3.12e+08	2.90e+07	644750	850000	8.5	13619
6	S. Yucca	32.30	9.00e+08	8.37e+07	675000	800000	7.4	11904
	Plutonium							
11	Valley	3.37	9.40e+07	8.73e+06	705000	809000	6.3	10064
	PIN STRIPE	0.56	1.57e+07	1.46e+06	706000	777000	11.9	19138

# Contaminated Soils Areas (McArthur, 1991)

a	<sup>240</sup> Pu	<sup>60</sup> Co	<sup>137</sup> Cs	<sup>90</sup> Sr	<sup>152</sup> Eu	<sup>154</sup> Eu	<sup>155</sup> Eu
4	1	2.8	4.8	7.2	21.3	2.2	0.6
16	2.04	0.1	3.5	11.7	0	0	0
<b>7</b> 2	1.18	0.1	1	1.5	0	0	0
64	0.66	0.1	1.1	1.6	0	0	0
84	0.96	1.6	4	11.2	19.4	0.7	0.1
24	1.06	0.7	10.4	27	0.3	0	0.3
48	1.12	0.4	9	18	0.4	0	0.1
5.2	1.3	0.7	5.3	13.1	0	0	0
68	5.42	1.8	8.5	28.1	24.4	1.1	0.6
1.2	0.3	0.1	0.6	2	€_0	0 $\not\succeq$	0
48	1.62	0.4	5	16.4	0	$\Rightarrow$ 0	0
84	6.96	3.9	10.8	14	13	0.9	0.2
2.4	0.6	0.1	2	4.4	0	0	0
2	0.5	0.6	<b>Д</b> >3	1.6	0	0	0
96	2.24	2.1	₹ <u>2</u> \$	6.1	29.9	2.4	0.4
92	0.98	0.3	33	7.2	0	0	0
88	0.72	8.9	26.4	6.6	0	0	0
36	21.34	2.1	13.4	17.1	6	0.4	0.7
84	0.46	4.2	9.8	13.8	0	. 0	0
48	15.72	1.5	7	13.3	31	2.9	0.4
88	2.72	0.3	3.2	6.2	0	0	0
88	20.22	24.7	83.7	68.4	3	4.2	6
24	1.06	0.6	16	13.1	0	0	0
04	4.26	0.3	8.8	12.1	0	9	0
04	2.26	1.4	9.2	14	0	0	0
72	1.28	0.4	3.3	5	0	0	0
3.2	5.8	0	0.4	0.2	0	0	0
0	0	0	0.2	0.2	0	0	0

### (Ci) at Contaminated Soils Areas

	Total Ci	Percent of Total	Rank	Cumulative Percent
	327.9	21.93	1	21.93
	169.0	11.30	2	33.23
	137.2	9.17	3	42.40
	97.3	6.51	4	48.91
	95.0	6.35	5	55.26
	56.8	3.80	6	59.06
	56.1	3.75	7	62.81
Y	47.1	3.15	8	65.96
	46.9	3.14	9	69.10
	46.8	3.13	10	72.23
	43.6	2.92	11	75.14
	40.5	2.71	12	77.85
	37.2	2.49	13	80.34
	37.0	2.47	14	82.81
	33.4	2.23	15	85.05
	31.6	2.11	16	87.16
	30.8	2.06	· 17	89.22
	28.8	1.93	18	91.15
	27.7	1.85	19	93.00
	24.2	1.62	20	94.62
	21.7	₩ 1.45	21	96.07
	16.6	1.11	22	97.18
	12.0	0.80	23	97.98
	10.0	0.67	24	98.65
	8.1	0.54	25	99.19
	7.2	0.48	26	99.67
	4.5	0.30	27	99.97
	0.4	0.03	28	100.00
	1495.4	100		

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## Area 3 RWMS    (m)   304.8   4027.1   4267.2   4286.4   4364.1   4770.9   5244.0   5526.6   6188.6   7004.6   8769.2   9871.9   9899.7   10064.2   11412.3   11515.1   11903.8   12391.9   13031.6   13619.4   13624.7   14379.0   14461.9   15471.4   15987.1   17504.2   19124.7   19137.6	

ბ÷ეეებ	3.0e-6	3.6 1.6e-5	1.4e2 5.9e-4	0.0091 4.0e-8	0.28 1.2e-6	0.029 1.3e-7	0.066 2.9e-7	3 10-4
7:20:7	3.2e-7	4.4e-6	7.8e-5	3.6e-9	2.6e-7	1.2e-8	6.1e-8	1 30-10
₹ <u>₽₽:</u> 9	0.089	1.2	21	9.8e-4	0.070	0.0034	0.017	3 4P-5
57 32.7	7.7e-8	1.7e-6	2.2e-5	7.9e-10	8.9e-8	2.7e-9	1.3e-8	2.7e-11
3	0.0084	0.19	2.4	8.7e-5	0.0098	2.9e-4	1.4e-3	3.0e-6
	100	10.7	28.8	1.53e6	16.1	2.03e4	2.13e5	6.5e6
** *	63Ni	$^{85}\mathrm{Kr}$	JS <sub>06</sub>	$^{12}$ Er	$qN_{m_{E6}}$	<sup>94</sup> Nb	$^{99}\mathrm{Tc}$	107pd

Table 2.7 (continued)

Nuclide	Half-Life (vrs)	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (Cl/m³)	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (CVm <sup>3</sup> )	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure
л. т.	1.91	2.9e-3	2.6e-8	0.0092	3.4e-8	0.058	2.5e-7
4T <sup>622</sup>	7.34e3	3.46-6	3.1e-11	4.4e-4	1.6e-9	5.66-5	2.5e-10
<sup>230</sup> Th	7.54e4	3.8e-4	3.5e-9	0.0011	4.2e-9	8.1e-5	3.6e-10
<sup>232</sup> Th	1.40e10	4.3e-3	4.0e-8	0.0082	3.0e-8	0.016	7.0e-8
<sup>231</sup> Pa	3.28e4	1.6e-6	1.5e-11	8.2e-5	3.0e-10	2.4e-5	1.0e-10
$\Omega_{252}$	68.9	5.5e-4	5.00	0.0057	2.1e-8	0.042	1.8e-7
$\Omega^{\epsilon\epsilon z}$	1.59e5	3.6e-2	3.3e-7	0.41	1.5e-6	0.023	1.0e-9
234U	2.44e5	0.99	9.0e-6	11	4.0e-5	0.25	1.1e-6
$\Omega^{25}$	7.04e8	3.2e-2	2.9e-7	0.33	1.2e-6	0.043	1.9e-7
<sub>236</sub> U	2.34e7	1.2e-3	1.1e-8	0.04	4.9e-8	0.0014	5.9e-9
$\Omega_{8cz}$	4.47e9	1.1	1.0e-5	12	4.3e-5	0.56	2.4e-6
237×1	7 11 0			•	•		•



Table 2.7 (continued)

Estimated (Tris)         Concentration at Closure (CI)         Estimated (CI)         Concentration at Closure (CI)         Estimated (CI)         Concentration (CI)         Estimated (CI)         Concentration (CI)         Estimated (CI)         Concentration (CI)         Inventory at (			U-3	U-3bh	U-3ah/at	h/at	U-3	U-3ax/bl
14.1       1.5e-3       1.4e-8       0.011         55       7.2e-3       6.6e-8       0.066         1.0e5       7.9e-5       7.2e-10       9.0e-4         1.57e7       1.8e-6       1.7e-11       2.1e-5         2.3e6       6.5e-5       6.0e-10       7.5e-4         30.2       3.1       2.9e-5       7.5e-4         90       0.10       9.5e-7       1.1         36       1.3e-4       1.2e-9       0.0013         13.6       0.092       8.4e-7       0.65         8.6       0.069       6.3e-7       0.35         1.2e3       1.9e-8       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051         5.75       3.0e-3       2.7e-8       0.0051	Nuclide	Half-Life (yrs)	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (CVm³)	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (Ci/m²)	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (Ci/m²)
55       7.2e-3       6.6e-8       0.066         1.0e5       7.9e-5       7.2e-10       9.0e-4         1.57e7       1.8e-6       1.7e-11       2.1e-5         2.3e6       6.5e-5       6.0e-10       7.5e-4         30.2       3.1       2.9e-5       7.5e-4         30.0       0.10       9.5e-7       1.1         36       1.3e-4       1.2e-9       0.0013         13.6       0.092       8.4e-7       0.65         8.6       0.069       6.3e-7       0.36         1.2e-3       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	рЭшен	14.1	1.5e-3	1.4e-8	0.011	4.0e-8	0.18	7.3e-7
1.0e5       7.9e-5       7.2e-10       9.0e-4         1.57e7       1.8e-6       1.7e-11       2.1e-5         2.3e6       6.5e-5       6.0e-10       7.5e-4         30.2       3.1       2.9e-5       7.5e-4         90       0.10       9.5e-7       1.1         36       1.3e-4       1.2e-9       0.0013         13.6       0.069       8.4e-7       0.65         8.6       0.069       6.3e-7       0.39         1.2e3       1.9e-8       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	121mSn	55	7.2e-3	6.6e-8	990.0	2.4e-7	0.50	2.2e-6
1.57e7       1.8e-6       1.7e-11       2.1e-5         2.3e6       6.5e-5       6.0e-10       7.5e-4         30.2       3.1       2.9e-5       27         90       0.10       9.5e-7       1.1         36       1.3e-4       1.2e-9       0.0013         13.6       0.092       8.4e-7       0.65         8.6       0.069       6.3e-7       0.39         1.2e-3       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	126Sn	1.0e5	7.9e-5	7.2e-10	9.0e-4	3.3e-9	0.0084	3.6e-8
2.3e6       6.5e-5       6.0e-10       7.5e-4         30.2       3.1       2.9e-5       27         90       0.10       9.5e-7       1.1         36       1.3e-4       1.2e-9       0.0013         13.6       0.092       8.4e-7       0.65         8.6       0.069       6.3e-7       0.39         1.2e-3       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	I <sub>621</sub>	1.57e7	1.8e-6	1.7e-11	2.1e-5	7.6e-11	1.9e-4	8.3e-10
30.2 3.1 2.9e-5 7 1.1  90 0.10 9.5e-7 1.1  36 1.3e-4 1.2e-9 0.0013  13.6 0.092 8.4e-7 0.65  8.6 0.069 6.3e-7 0.30  1.2e-3 1.9e-8 1.7e-13 2.1e-7  22.3 4.7e-4 4.2e-9 5.8e-7  1.60e3 1.2e-3 1.1e-8 3.8e-6  5.75 3.0e-3 2.7e-8 0.0051	135Cs	2.3e6	6.5e-5	6.0e-10	7.5e-4	2.7e-9	0.0068	3.0e-8
90 0.10 9.5e-7 1.1 36 1.3e-4 1.2e-9 0.0013 13.6 0.092 8.4e-7 0.65 8.6 0.069 6.3e-7 0.30 1.2e-3 1.9e-8 1.7e-13 2.1e-7 22.3 4.7e-4 4.2e-9 5.8e-7 1.60e3 1.2e-3 1.1e-8 3.8e-6 5.75 3.0e-3 2.7e-8 0.0051	<sup>137</sup> Cs	30.2	3.1	2.98-51	27	9.96-5	1.8e2	7.6e-4
36       1.3e-4       1.2e-9       0.0013         13.6       0.092       8.4e-7       0.65         8.6       0.069       6.3e-7       0.30         1.2e3       1.9e-8       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	mS <sub>151</sub>	06	0.10	9.5e-7	1.1	4.0e-6	0.6	3.9e-5
13.6       0.092       8.4e-7       0.65         8.6       0.069       6.3e-7       0.30         1.2e3       1.9e-8       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	n <sub>3051</sub>	36	1.3e-4	1.2e-9	0.0013	4.6e-9	0.013	5.6e-8
8.6 0.069 6.3e-7 0.30 1.2e-3 1.9e-8 1.7e-13 2.1e-7 22.3 4.7e-4 4.2e-9 5.8e-7 1.60e3 1.2e-3 1.1e-8 3.8e-6 5.75 3.0e-3 2.7e-8 0.0051	152Eu	13.6	0.092	8.4e-7	0.65	2.4e-6	2.5	1.1e-5
1.2e3       1.9e-8       1.7e-13       2.1e-7         22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	154Eu	8.6	690.0	6.3e-7	0.39	1.4e-6	06.0	3.9e-6
22.3       4.7e-4       4.2e-9       5.8e-7         1.60e3       1.2e-3       1.1e-8       3.8e-6         5.75       3.0e-3       2.7e-8       0.0051	0Н <sub>ш991</sub>	1.2e3	1.9e-8	1.7e-13	2.1e-7	7.7e-13	1.9e-6	8.1e-12
1.60e3 1.2e-3 1.1e-8 3.8e-6 5.75 3.0e-3 2.7e-8 0.0051	<sup>210</sup> Pb	22.3	4.7e-4	4.2e-9	5.8e-7	2.1e-12	1.5e-7	6.6e-13
5.75 3.0e-3 2.7e-8 0.0051	<sup>226</sup> Ra	1.60e3	1.2e-3	1.1e-8	3.8e-6	1.4e-11	5.8e-7	2.5e-12
3.7.1	<sup>228</sup> Ra	5.75	3.0e-3	2.7e-8	0.0051	1.96.1	0.015	6.5e-8
2.16-12 1.76-3	<sup>227</sup> Ac	21.8	2.3e-7	2.1e-12	1.7e-5	6.2e-11	7.6e-6	3.3e-11

1.9e-5

4.5

1.8e-5

4.9

4.5e-4

20

14.4

241Pu

2.9e-9 6.0e-6

6.6e-4

4.9e-10

1.3e-4

8.1e-9

8.7e-4

3.76e5

<sup>242</sup>Pu

1.4

2.4e-6

0.65

7.10e51

7.8

432

<sup>241</sup>Am

5.9e-5 0.029

5.2e-6

7.38e3

<sup>243</sup>Am

3.3e-8

3.7e-3

18.1

<sup>244</sup>Cm

 $Total^{\dagger}$ 

6.5e2

0.0019

2.1e2

2.1e-9

5.8e-7 0.029

4.9e-6

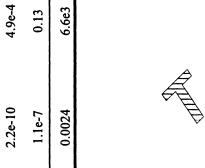
3.0e-6

0.82

9.5e-5

6.57e3

 $^{240}$ Pu



† - Total includes short-lived progeny in equilibrium.

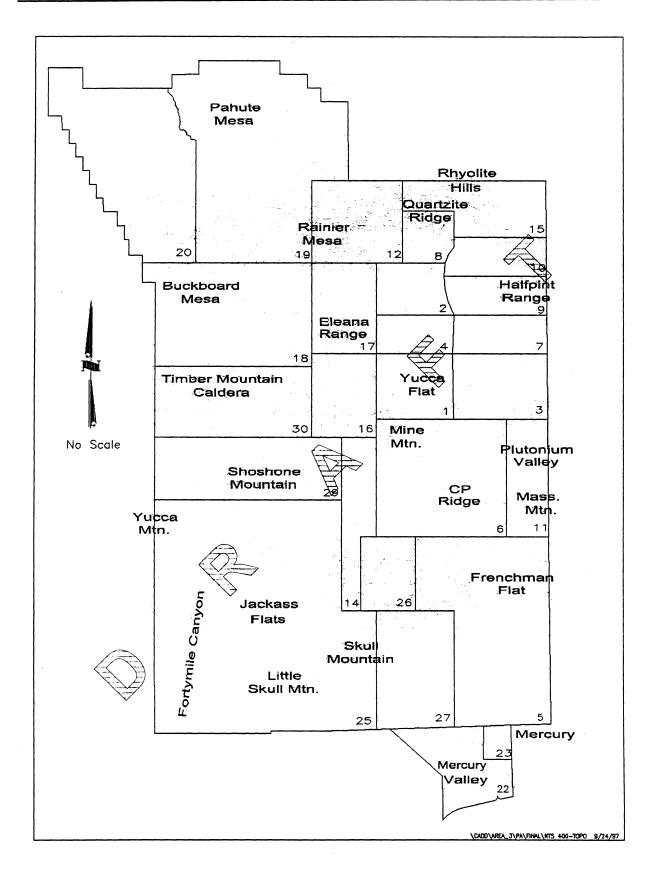


Figure 2.2 Topography of the Nevada Test Site

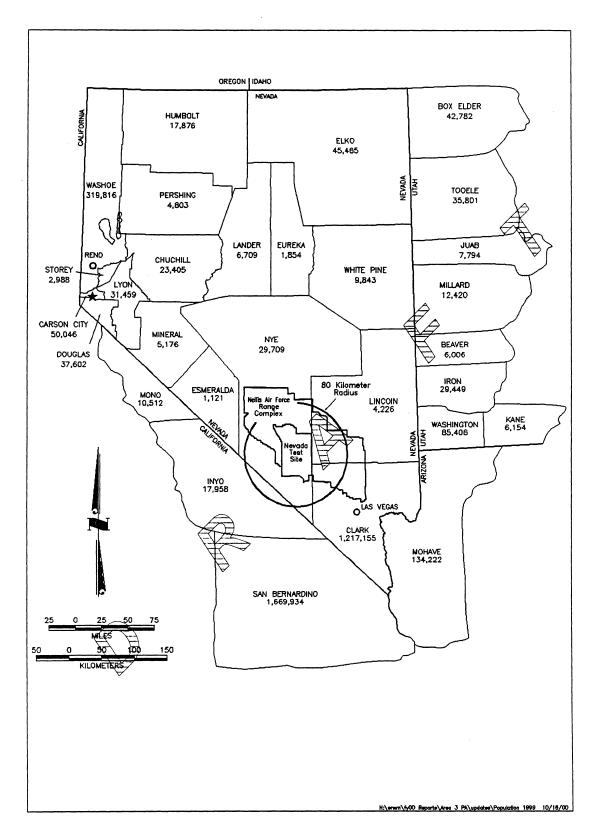


Figure 2.3 Population of Counties of Nevada, Southeastern California, Western Utah, and Northwestern Arizona

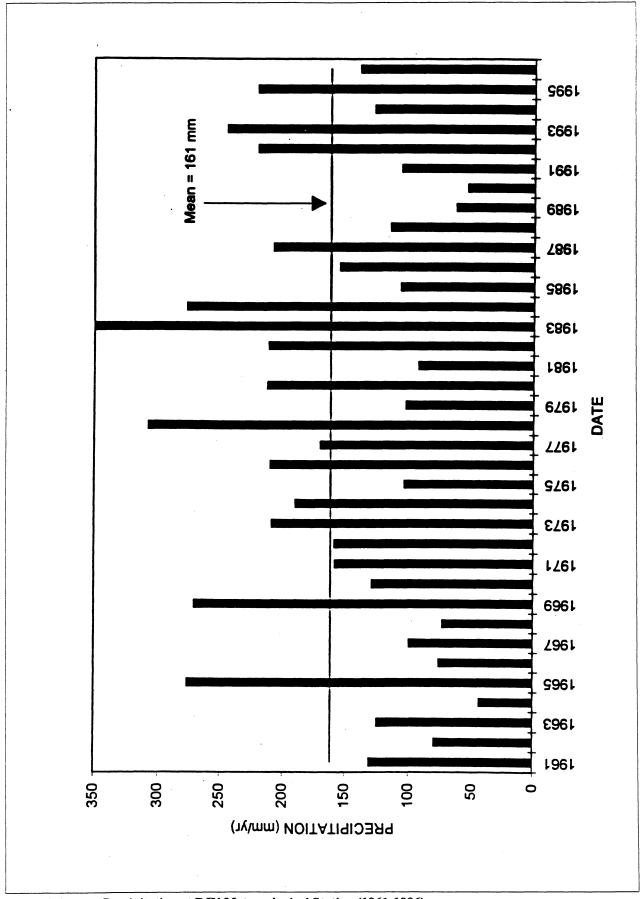


Figure 2.4 Precipitation at BJY Meteorological Station (1961-1996)

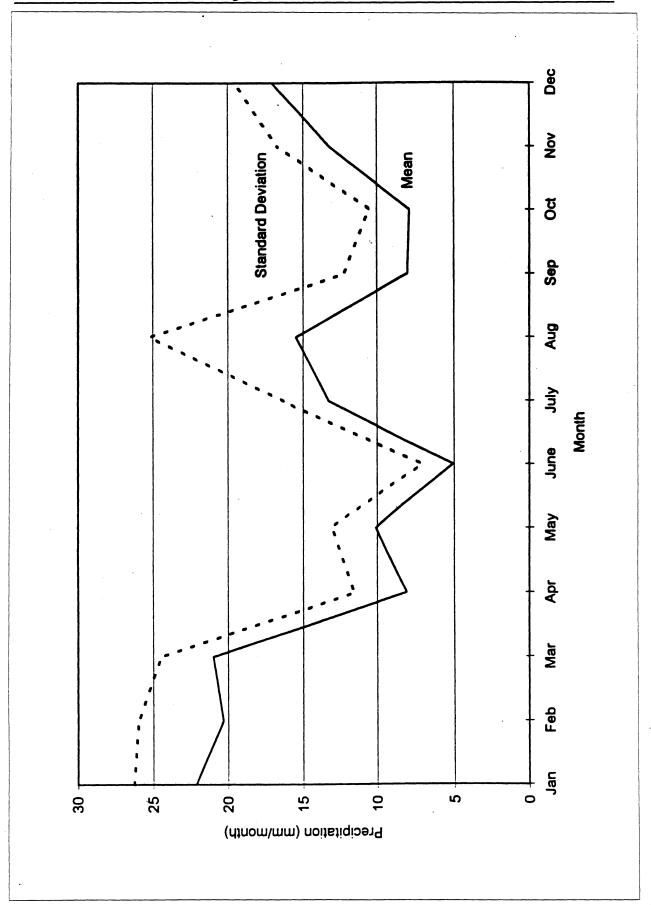


Figure 2.5 Monthly Precipitation at BJY Meteorological Station (1961-1996)

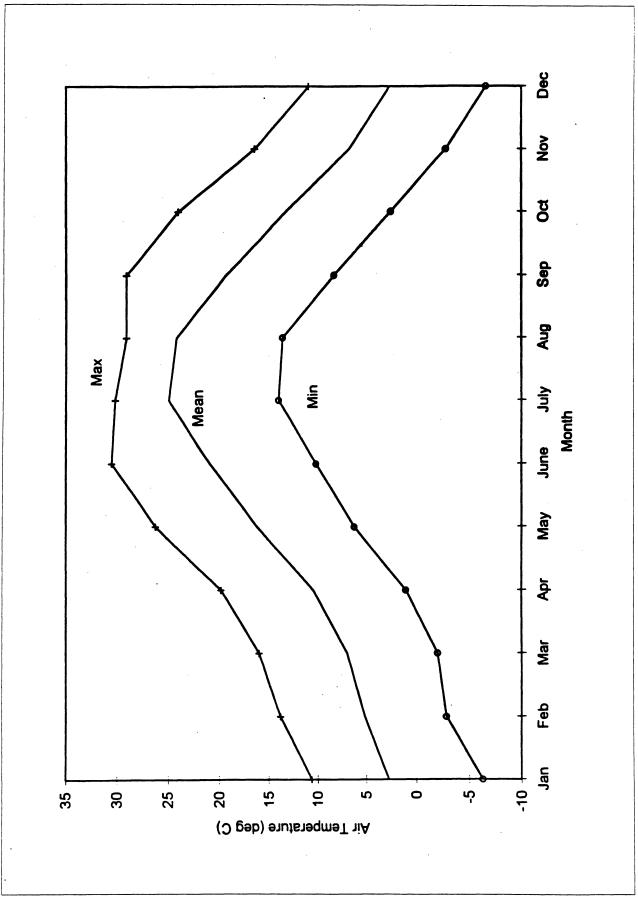


Figure 2.6 Monthly Air Temperature at Yucca Flat (1962-1978)

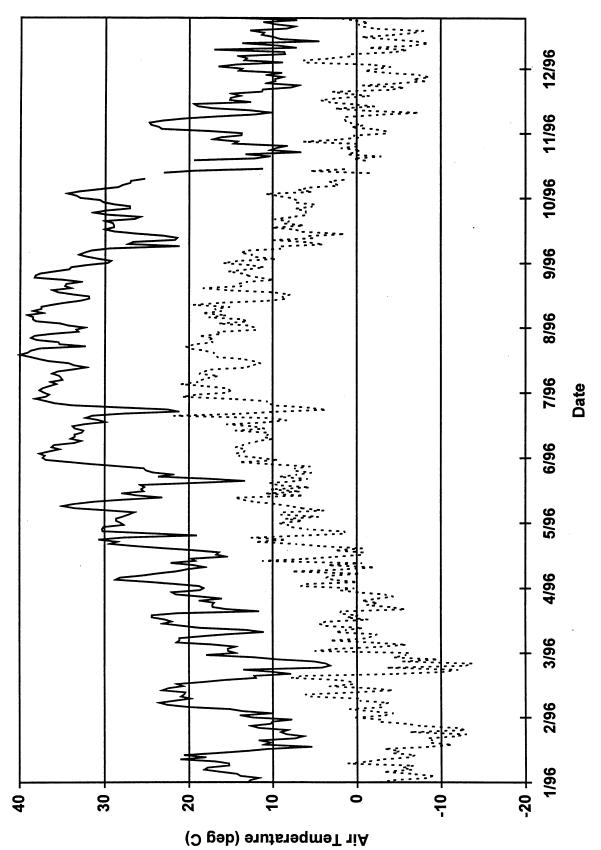


Figure 2.7 Daily Maximum and Minimum Air Temperatures at Area 3 RWMS Meteorological Station

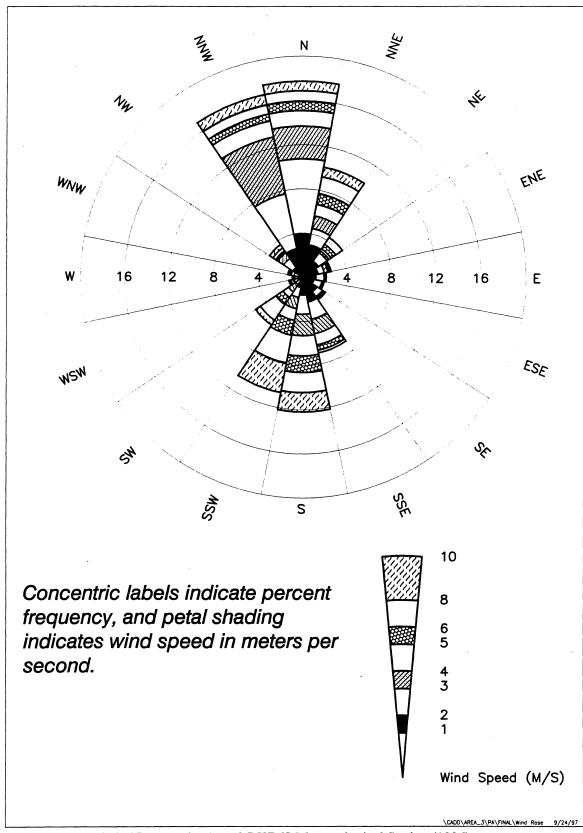


Figure 2.8 Wind Rose at the Area 3 RWMS Meteorological Station (1996)

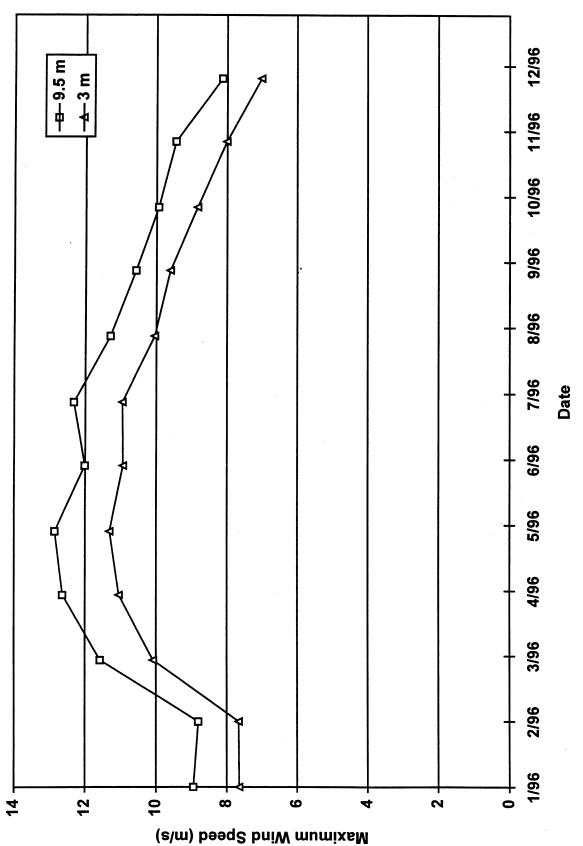
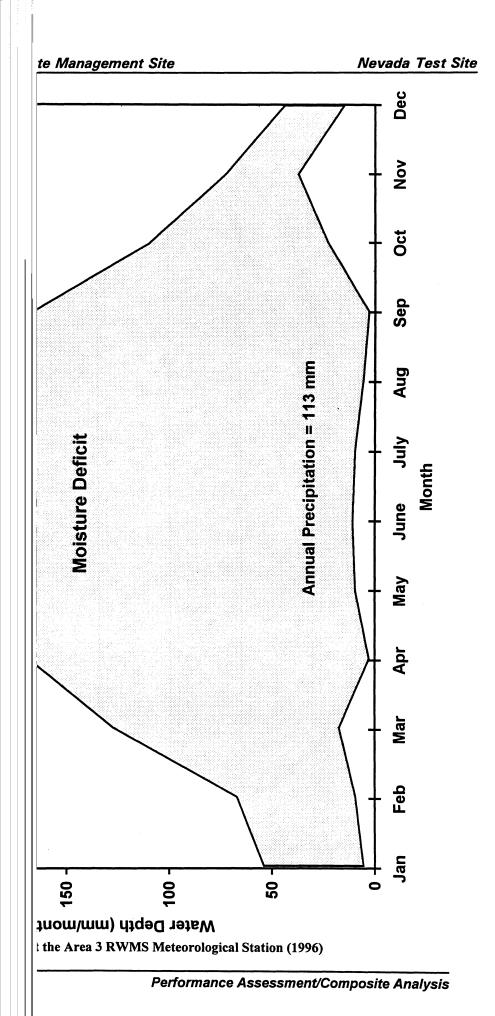


Figure 2.9 Monthly Average of Daily Maximum Wind Speeds at the Area 3 RWMS



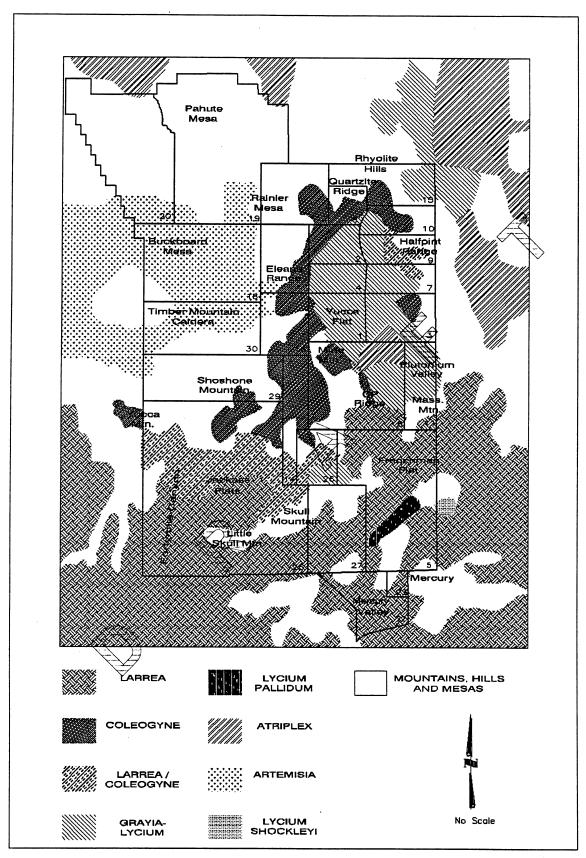
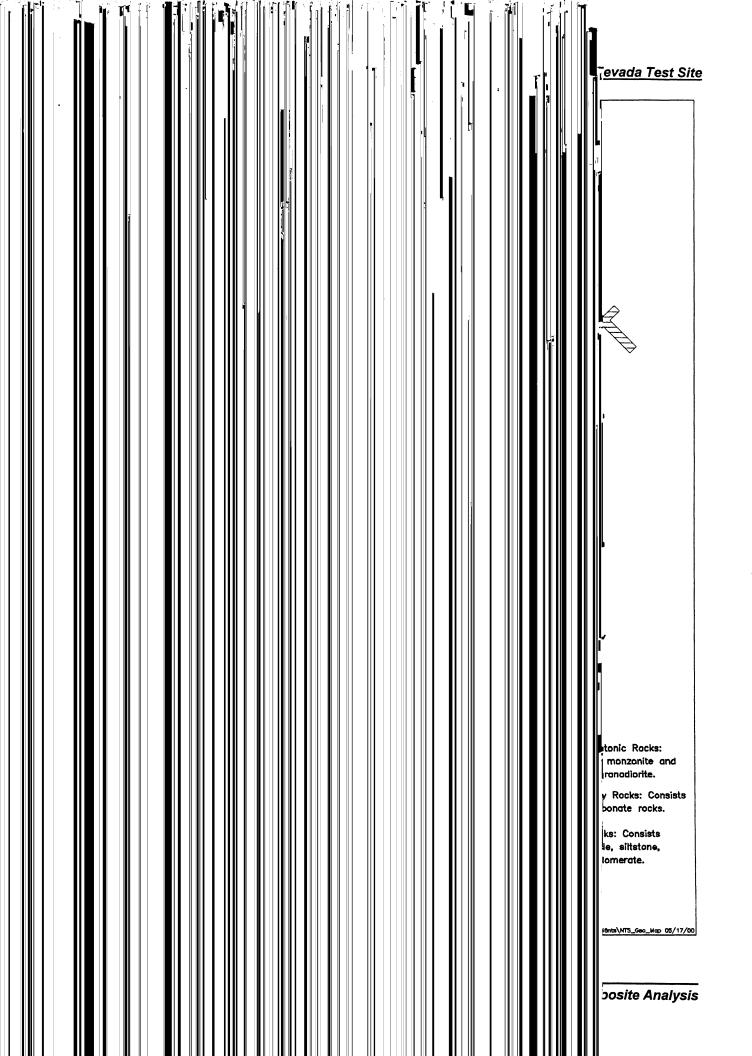
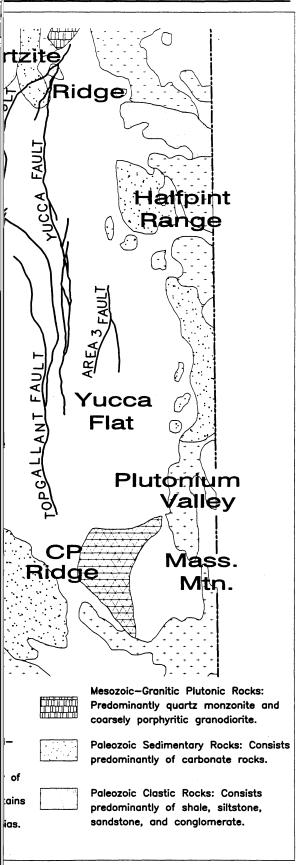
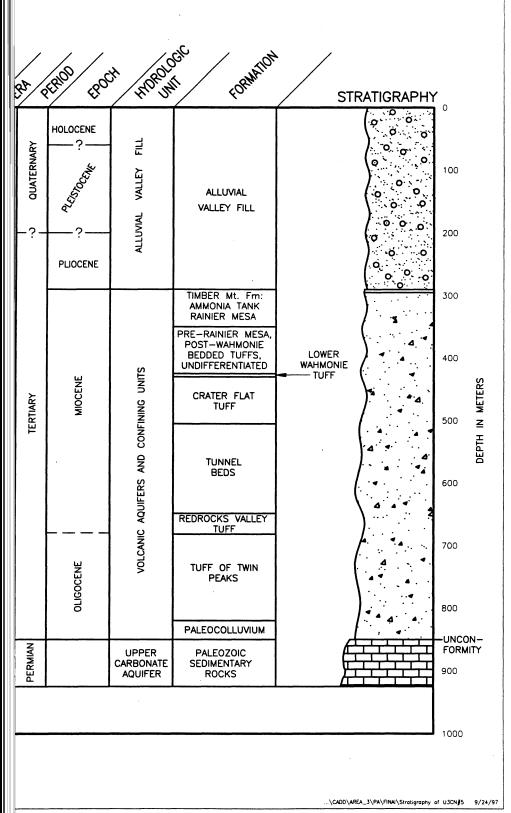


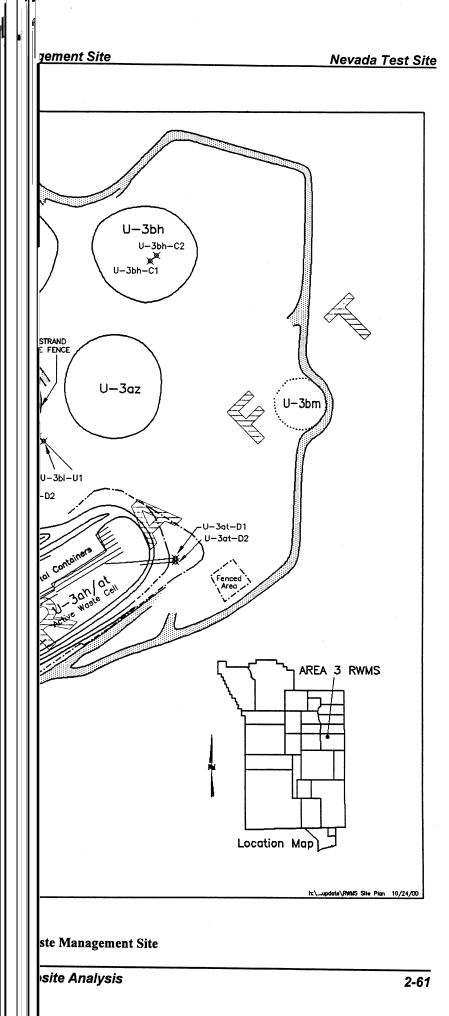
Figure 2.11 Distribution of Vegetation at the Nevada Test Site

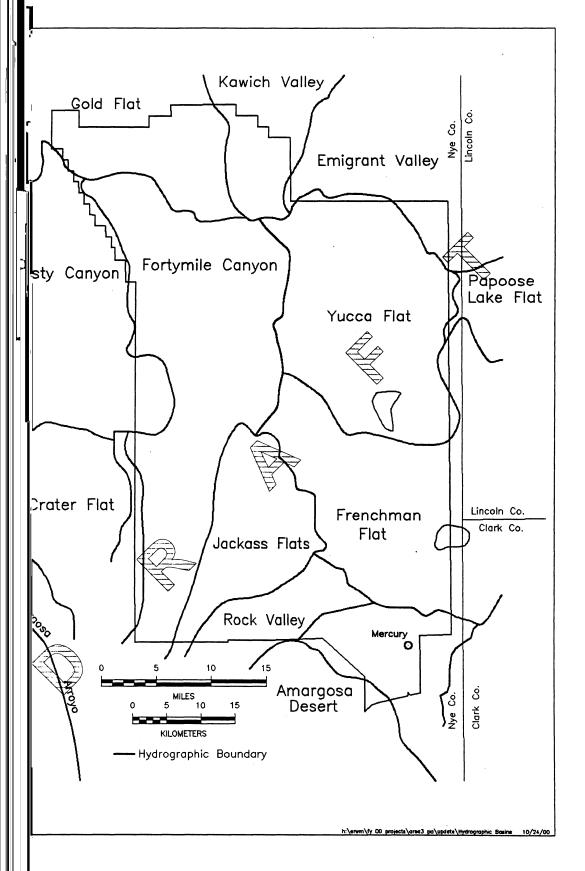






The Stratigraphy of Borehole U-3cn #5





Hydrographic Basins of the NTS

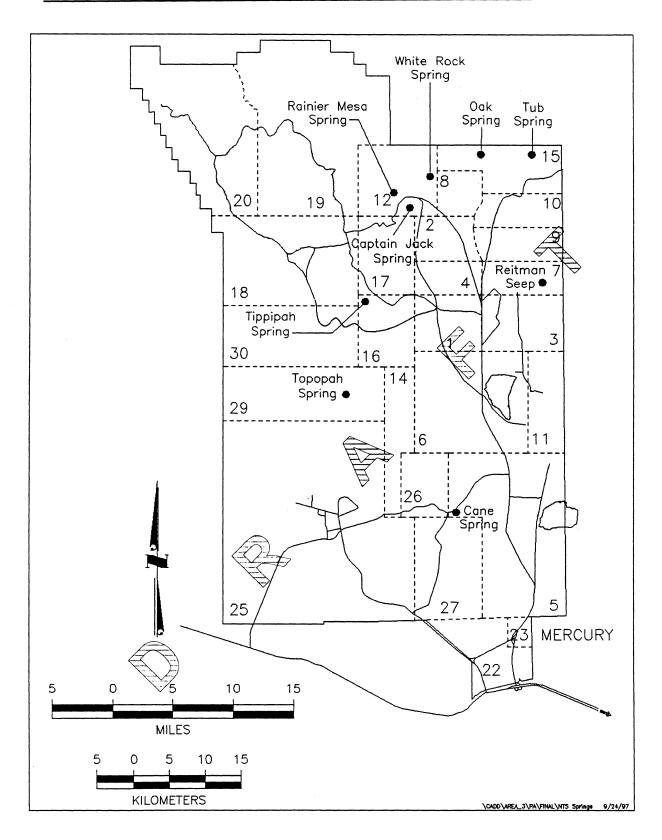


Figure 2.17 Location of Springs on the Nevada Test Site

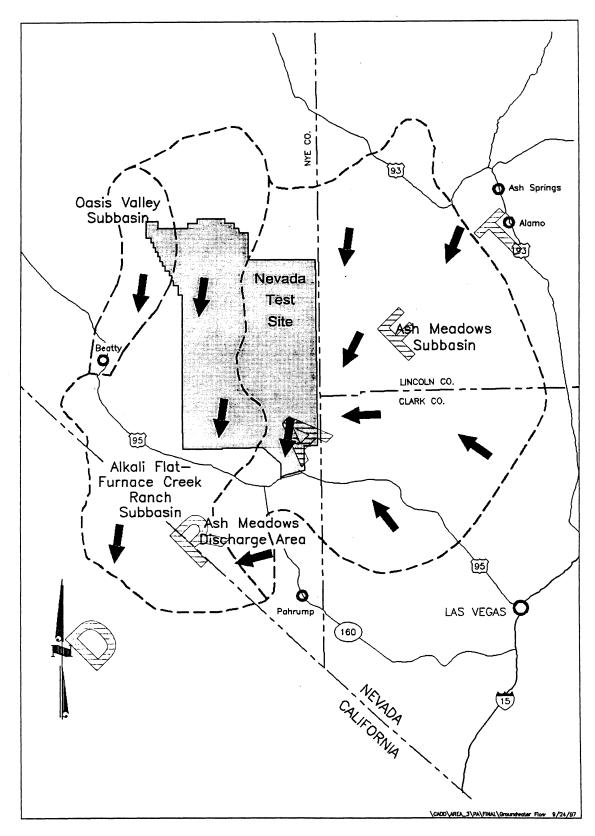
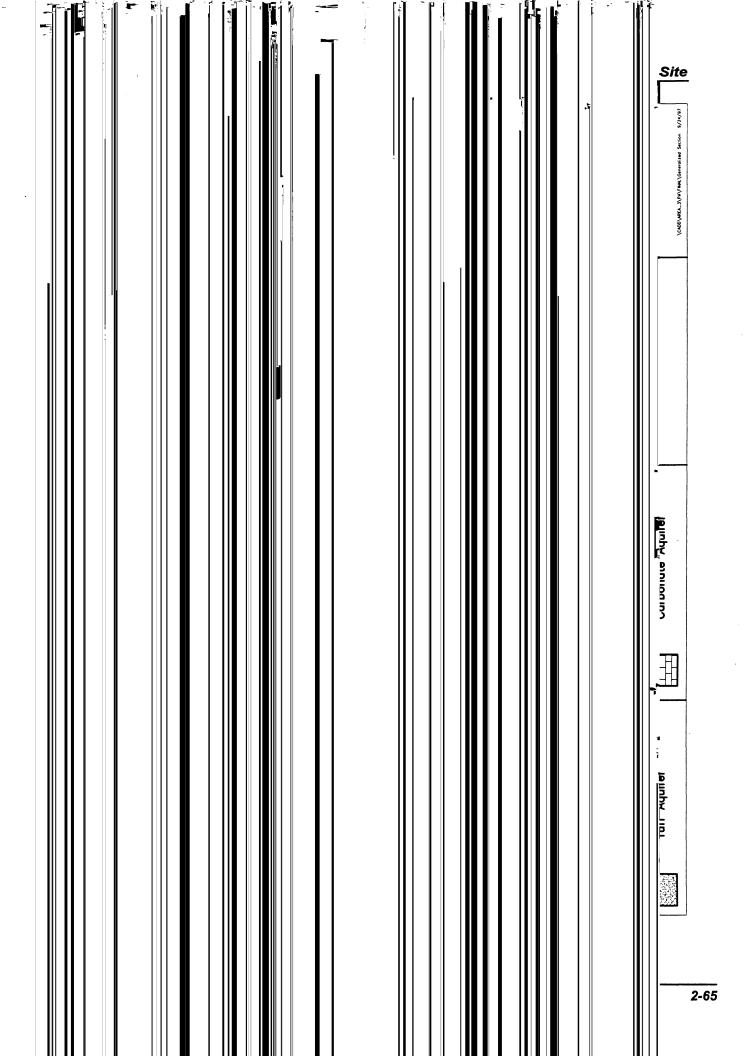
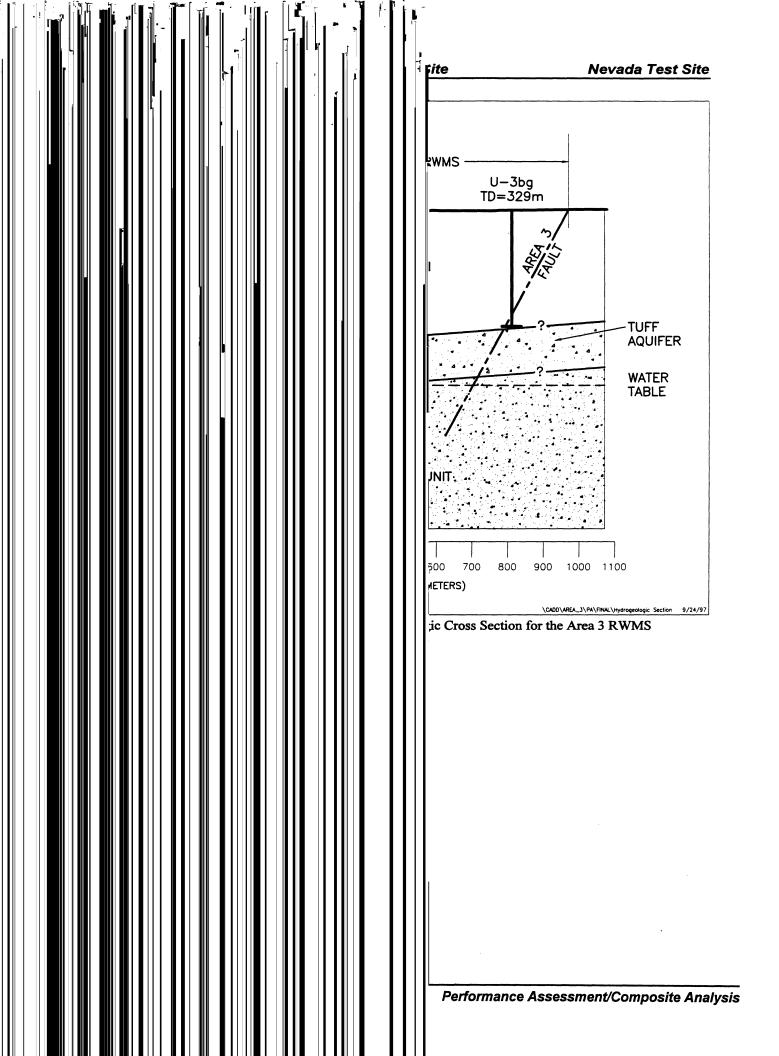
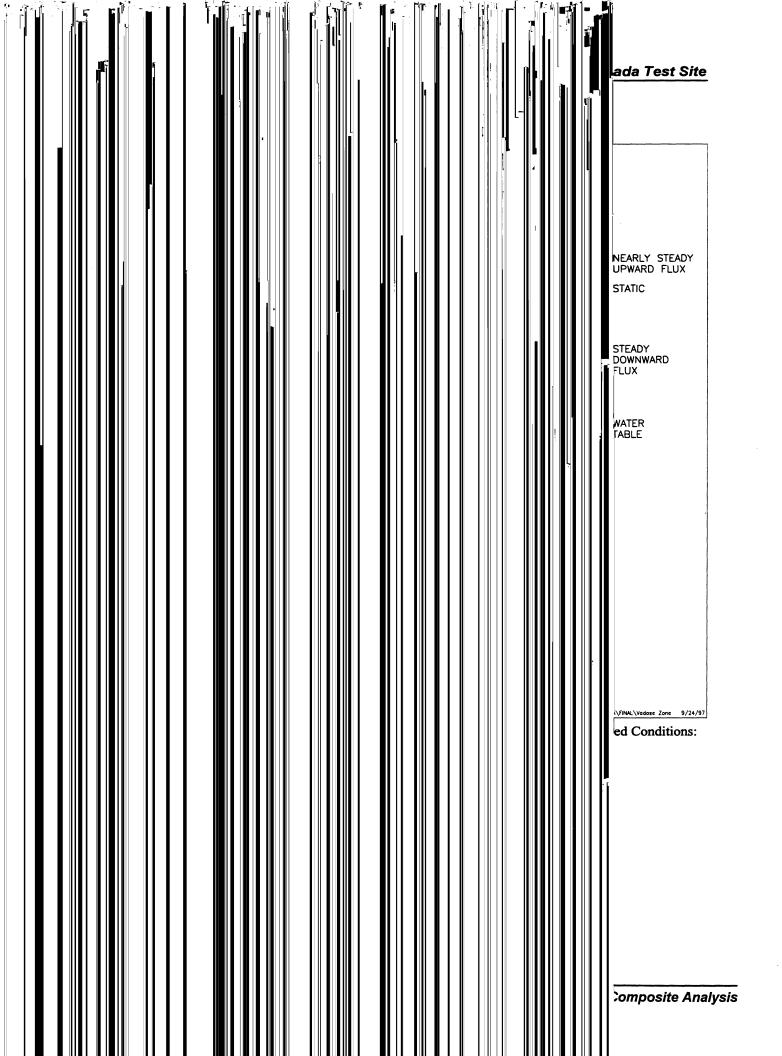
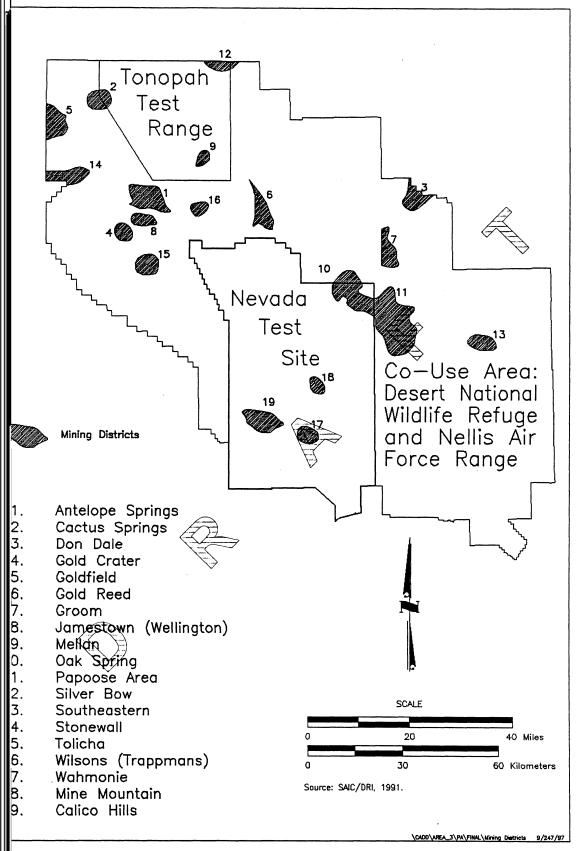


Figure 2.18 Principal Groundwater Subbasins and General Groundwater Flow Directions in the Nevada Test Site Area (from Laczniak et al., 1996)









ure 2.23 Mining Districts Located in the NTS, Tonopah Test Range, and NAFR Complex

# Nevada Test Site

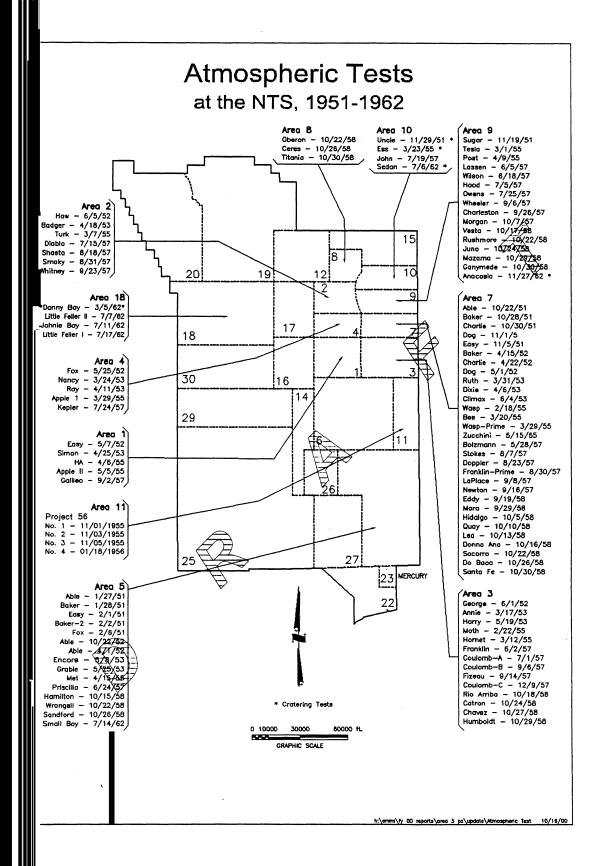


; and others (1988)

xcts\area3\update\Oil and Gae 10/24/00

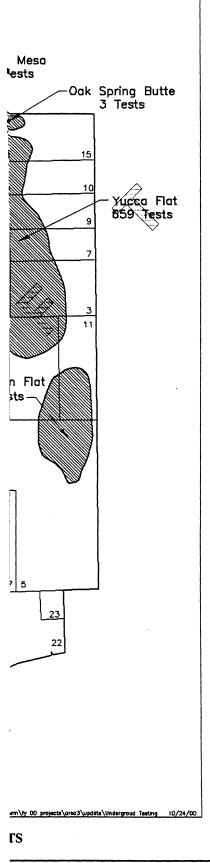
es Near the Area 3

/Composite Analysis



e 2.25 Atmospheric Tests Conducted at the Nevada Test Site (1951 to 1962)

mance Assessment/Composite Analysis





#### **FORMANCE**

and the technical basis for the determination of a nce with the performance objectives for a period of 1,000 h/at and U-3bh disposal units. Methods for both the PA

eds sequentially through the following steps:

nventory at closure for the PA and CA. Determination of ifying all sources of radioactive materials which may s from the U-3ah/at and U-3bh disposal units.

model of site performance. This includes conceptual ionuclide release and transport, and exposure pathways.

on of mathematical models representing the conceptual values for mathematical models.

indent concentration of radioniclides in accessible soil, and water).

each radionuclide as the product of a PDCF and the n accessible environmental media. The TEDE for each d as the sum of the TEDEs for all radionuclides and the performance objective.

nmental media concentrations and the PDCFs used to nte Carlo simulations which allow for direct incorporation the process. The expected value of the derived TEDE nst the performance criteria to establish compliance. The ethods in nontechnical terms, as much as possible, to cesses, and reference the appendices where comprehensive ., models, assumptions, parameters, treatment of is) is provided.

ual model of the source terms. The source term conceptual inventory, the waste form, the disposal unit, and the closure e previously described the Area 3 RWMS, its inventory, naterial potentially contributing to doses at the RWMS.

#### nent Source Term

erformance assessment is limited to the inventory at closure sal units. These are the only Area 3 RWMS disposal units mentation of DOE Order 5820.2A. The method of

g the U-3ah/at and U-3bh inventory at closure, the assumptions made, and the of inventory uncertainty are summarized in Section 2.5, "Waste Inventory." The information is provided in Appendix 2.

#### All-Pathways Analysis

atory considered in the all-pathways analysis includes the entire inventory estimated Vat at closure (Table 2.7). A portion of this inventory was disposed in U-3bh during on of the PA. This analysis assumes that the entire inventory is in these two units. nuclide concentration is assumed to be homogeneous throughout the disposal unit. ling purposes, the inventory is divided into volatile and nonvolatile radionuclides. lides considered to be exclusively volatile are <sup>39</sup>Ar, <sup>85</sup>Kr, <sup>219</sup>Rn, <sup>220</sup>Rn, and <sup>222</sup>Rn. se and transport of radon isotopes are not estimated for the all-pathways analysis DOE guidance (DOE, 1996a). Tritium and <sup>14</sup>C are assumed to be present in volatile blatile forms. As the partitioning of <sup>3</sup>H and <sup>14</sup>C between volatile and nonvolatile ınknown, it is conservatively assumed that the full inventory of <sup>3</sup>H and <sup>14</sup>C is for release in both a volatile and nonvolatile form. The volatile forms of <sup>3</sup>H and <sup>14</sup>C led to be tritiated water (HTO) and CO<sub>2</sub>, respectively. Assuming volatile <sup>3</sup>H is HTO is conservative because the dose from this form is significantly higher than elemental form. Carbon dioxide is the expected form of volatile <sup>14</sup>C given the dry itions at the site. All other radionuclides are assumed to be present in nonvolatile br dosimetry purposes, nonvolatile radionuclides are assumed to be in a form with t dose factor (DF) with some important exceptions. Strontium is assumed to be a form other than SrTiO<sub>3</sub>. Chlorine is assumed to be present as the chloride anion nis is the most common environmental form. Thorium and plutonium are assumed ent in oxide forms based on information provided by generators.

of waste forms disposed in U-3ah/at and U-3bh are known, but their quantitative ns are poorly known. Common waste forms on a volume basis are believed to sil, construction debris, and compactible trash. Because quantitative information g the waste is not available, simple conservative assumptions are made. The init is assumed to be filled with a single homogeneous waste form with conservative ide release properties. All radionuclides are assumed to be immediately available e. Waste form and containers are not assumed to retard release. Nonvolatile ides are assumed to be adsorbed onto a soil-like material. All volatile radionucept H, are assumed to be available for immediate release to the air-filled pore platile H is assumed to be released to the air-filled pore space as HTO. The ctivity of water vapor in the air-filled waste pore space is assumed to be equivalent cific activity of waste pore water.

h/at disposal unit was formed from two adjacent subsidence craters. Waste are expected to be disposed on seven tiers separated with clean 1-m (3-ft) soil of August 1997, all disposals in U-3bh had consisted of uncontainerized soils. The period of the properties of the transfer of the t

#### Nevada Test Site

of homogeneous ted to retard e accessible

er alluvium cap.
action and
is expected to
tantaneously.
lence, erosion is
fter subsidence
ence is assumed
platile radionue increased
nd waste moisture

ap are the same

ts of <sup>222</sup>Rn. The evels while 98). The 1 the disposal unit. ste and trans-However, 1 aste source term

form will reach sion [NRC], as the emanation efficient is less

malysis are the

assumed for the

#### an Intruders

e intruder analysis is the same inventory as used for the pathway analyses. The IHI analyses assume that the waste soil at the time of intrusion. The radionuclide concentration is hroughout the waste disposal unit. The IHI scenarios assume unit. It is unlikely that an individual would select a subsided

#### is Source Term

ition potentially interacting at the Area 3 RWMS include the ites, UGTA, and Industrial Sites. The CA source term is ax/bl disposal unit and the Soil Sites in Yucca Flat and ground testing areas are not included as explained in tes are not included because they are believed to be a minor ites and remain uncharacterized.

bl disposal unit is modeled as for the other units. The soil Flat were created predominantly by atmospheric nuclear crater-forming nuclear weapons tests. A fraction of the assumed to be fused into large silicate particulates that are less ral soil particulates (Shinn *et al.*, 1986). Soil contamination assumed to be much more easily resuspended based on site-tal., 1986).

d cap are treated as for the other units. Waste is assumed to be ous layer. The cap is assumed to be 3 m (10 ft) thick at the end complete subsidence occurs.

# el of Radionuclide Release and Transport

scribes the processes that transport radionuclides from the onment. Conceptually, the transport process has been divided st component, the release and transport conceptual model esses the transport from the source term to one of three environ-oundwater) in the accessible environment. The second comual model described in Section 3.4, addresses the scenarios and the doses received from exposure to contaminated envisare developed based on the site characterization data and ster 2, hydrologic screening analyses presented in Appendix 1, n expert panel described in Appendix 5.

# ssment Conceptual Model

of the release and transport conceptual model from site bed in Appendix 3.

#### 3.2.1.1 All-Pathways Analysis

Release and transport models were developed for the nonvolatile and volatile source term.

**Nonvolatile Radionuclides.** Processes expected to transport the nonvolatile radionuclide source term to the accessible environment are:

- Advection and diffusion of solutes in soil pore water:
- Uptake, translocation, and senescence of plants rooted in the waste and cap soil;
- Physical transport of waste by animals burrowing into the waste and cap soil; and
- Resuspension and erosion of cap soil.

The surface water pathway as the secondary source of contaminants and, as an exposure pathway, is also ruled out in this assessment, since there are no sources of surface water near the Area 3 RWMS that are likely ever to be used as sources of drinking water. The PA scenarios are limited to features, events, and processes that are currently occurring or have occurred in the past. Current residents of southern Nevada obtain their drinking water from the Colorado River, its tributaries, or groundwater. Native Americans have used the Colorado River, its tributaries, springs and seeps, sandstone tanks, and flooded playas as sources of drinking water. With the exception of playas, these sources do not exist near the Area 3 RWMS. Yucca Flat playa collects storm runoff several times a year, but the water either evaporates or infiltrates shortly after the storms. Therefore, the playa cannot be considered a sustained source of water. There is also no evidence that runoff has been or is being collected in cisterns in alluvial valleys in this area.

The release and transport conceptual model assumes that the site is subsided throughout the compliance period. Two limiting cases are analyzed separately. In the first, the upward pathway is maximized. For this case, the current climatic conditions of high evapotranspiration and low precipitation are assumed to prevail in the future. Under these conditions, all precipitation infiltrating into the disposal unit returns to the atmosphere as evapotranspiration and no recharge occurs. Advection of solutes is assumed to be upwards in this case and corresponds to the undisturbed conditions, where the upward hydraulic gradients are the strongest. However, effects of subsidence are reflected in increased soil water content and formation of cracks, both of which affect transport of radionuclides. In the second case, the downward pathway is maximized by assuming that runoff-producing precipitation events cause runoff from the tributary drainage area to pond in the depression formed in the subsided closure cap. These ponding episodes will cause enhanced infiltration that would alter the soils moisture and result in possible recharge of groundwater which lies about 490 m (1,600 ft) below the facility floor. The hypothetical severity of the assumed ponding and the consequent advance of the wetting front toward groundwater bounds the observed wetting of the soil column resulting from historical infiltration episodes in the craters where the waste is emplaced. Hydrologic screening analyses of assumed ponding episodes described in Appendix 1 indicate that the travel time to the uppermost aquifer is likely to be greater than the 1,000-year compliance period. This rules out further consideration of the downward pathway.

# levada Test Site n of the plant orb radiooughout their ay, returning to the soil med to increase over the cap. construct gh to penetrate erefore, the 'ertebrate ap soil. ompliance it the complilysis, the concentraadvection off radionuclide illed pore i to create a rous medium. -driven zaroff, 1992). atmospheric advection was al model of aseous releases, y are assumed sis is the same posite Analysis

# Test Site lile nalyses t to the er ses, the ınit. ents/ radio-'l and r from ned to 0 ft) ruder ttings ver the tions erms in undary id the by in 100 m cated e nation MS.

#### Radionuclides

ne which nonvolatile mospheric pathway is exposed directly to imptions and paramibed in detail in nuclides causing a nuclides meeting the "9"Tc, 126Sn+D, .c+D, 238Pu, 238U+D, D. The "+D" notation be in equilibrium. the nonvolatile 1 CA.

arough the air-filled e flux at the cap oncentration profile is e expression considerre no sinks or sources e of subsidence. Gases ed as an area weighted

le air-filled pore space as tritiated water. The iressure. The specific assumed water content vaste pore space is

ate conditions and with onditions, method of andix 4.

dionuclides diffusing m (330-ft) compliance le boundary is esti-IHI analyses, volatile aneously into a mixing

<u>it Site</u> **1**89). n, the of I ion te by nsto SC) ng lities ties sti-tigle nodel the iuse form dels. 'nе :rm his alysis nes that the MOP works 40 hours per week at a remote site and y lifestyle. The MOP's time is divided between time at work, time dentary indoor activities, and time spent outdoors. The second s scenario uncertainty, called the community scenario with agri-MOP works at a remote site, but leads a slightly more active ivation of a small noncommercial garden and noncommercial

is, the MOP in the community scenario without agriculture is cleased from the site through (Figure 3.2):

ed soil particulates, idionuclides, adionuclides, n radionuclides in soil, and f soil.



ater is not included because analyses indicate that contamination of 0-year compliance period is unlikely. A complete description of 1 nd parameters used to calculate the all pathways PDCFs for the agriculture is provided in Appendix 7.

griculture on scenario uncertainty, the community scenario is l pathways (Figure 3-2)—Commercial and noncommercial agrit not impossible in southern Nevada. Irrigation-based commercial existent in southern Nevada at locations without shallow ground-Haggard, 1983; DOC, 1987). In the community scenario with sumed to maintain a small garden plot, range-fed beef cattle, and eters used to calculate the agricultural PDCFs are consistent with and the limited contaminated area available for agricultural use. ctivities are assumed to be noncommercial, it is assumed that arge-scale irrigation. Because some urban and rural residents of bles for personal consumption (EPA, 1984), the resident is quantities of leafy vegetables, root vegetables, and fruits on the tion is assumed to include irrigation from a groundwater source. grown for personal consumption in southern Nevada and are not ommercial and noncommercial livestock production does occur in 987). The resident is assumed to produce beef, milk, poultry, and on of a forage crop is assumed to be unreasonable for the location ivestock are assumed to consume contaminated natural forage and uced at an off-site location.

is, the MOP in the community with agriculture scenario is exposed om the site by:

oil,

attle, and poultry.

without agriculture. Groundwater consumption ogic analyses indicate that the aquifer is ,000-year compliance period. Inclusion of of time the MOP is outdoors. Soil mass icrease while the MOP is engaged in agriculused to calculate the all-pathways PDCFs for escribed in Appendix 7.

is

e same exposure scenarios as the all-pathways assumes that the MOP is exposed only to pheric pathway analysis, residents of the from the site by:

P in the community scenario with agriculture is rough the same pathways. However, in the P is assumed to lead a more active lifestyle that ulture. This is assumed to increase ventilation the amount of time spent outdoors.

I to be limited to excavation of a basement and commonly combined into three acute scenarios uder-construction scenario (NRC, 1981), and 1988). Chronic IHI scenarios are long-term trios. Two chronic IHI scenarios are commonly 1981) and postdrilling intruder scenario

le from the end of institutional control at 250,000 years. Because the waste is assumed to be

nd of institutional control, chronic IHI scenarios are of institutional control also. Previous work has shown that are assumed to occur at the same time, higher doses are n for acute scenarios for almost all radionuclides (Shott n, 1988) because acute exposures last a few hours or days, led to continue for a year. Therefore, only the chronic ig scenarios are evaluated below.

same land use and exposure pathways as the all-pathways rith agriculture (Figure 3.3). The intruder is assumed to be es in the contaminated zone and volatile radionuclides h:

articulates, ides, ides, uclides in soil,

range-fed cattle, and range-fed poultry.

umeters used to calculate the PDCFs are described in

an Intrusion. At sites with easy access to water, intrusion conservative to assume that intrusion will occur at the nce period, because intrusion is much less likely at a ence of intrusion is problematic, excessive and unrealistic counting for the site-specific probability of intrusion.

me event. The most widely accepted method for events is via quantification of the opinions of a panel of yer and Booker, 1991). An expert panel was convened to ertent intrusion into waste disposed in Yucca Flat will er mechanisms, judged much less likely to cause intrusion, rains details of the panel's conclusions and methods.

nan intrusion was calculated assuming 250 years of anel found continued institutional control plausible. The inadvertent human intrusion into disposal cell U-3ah/at, riod, at 0.0047.

Ιo

e exposure scenario and pathways as the community bathways analysis. The resident is assumed to be nuclides released from buried waste and through:

ates,

s in soil,

-fed cattle, and :-fed poultry.



assumed to differ only in the spatial distribution of oil contamination areas in Yucca Flat is potentially forage consumed by twestock is contaminated. sumed to be distributed uniformly with depth. waste disposal units is assumed to be distributed. The methematical models and parameters used to ribed in Appendix 7.



alysis 3-15

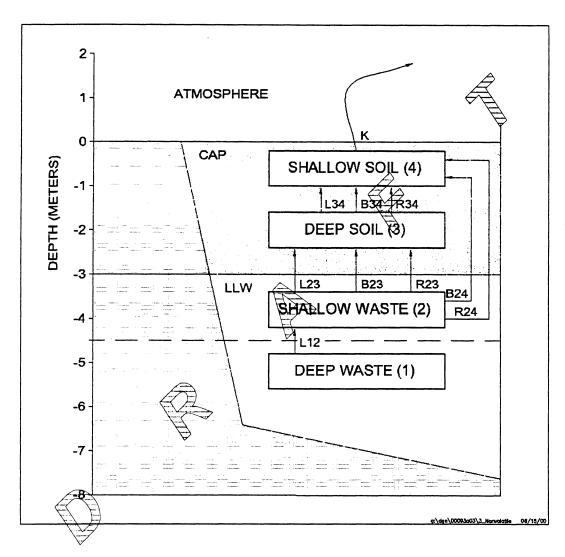
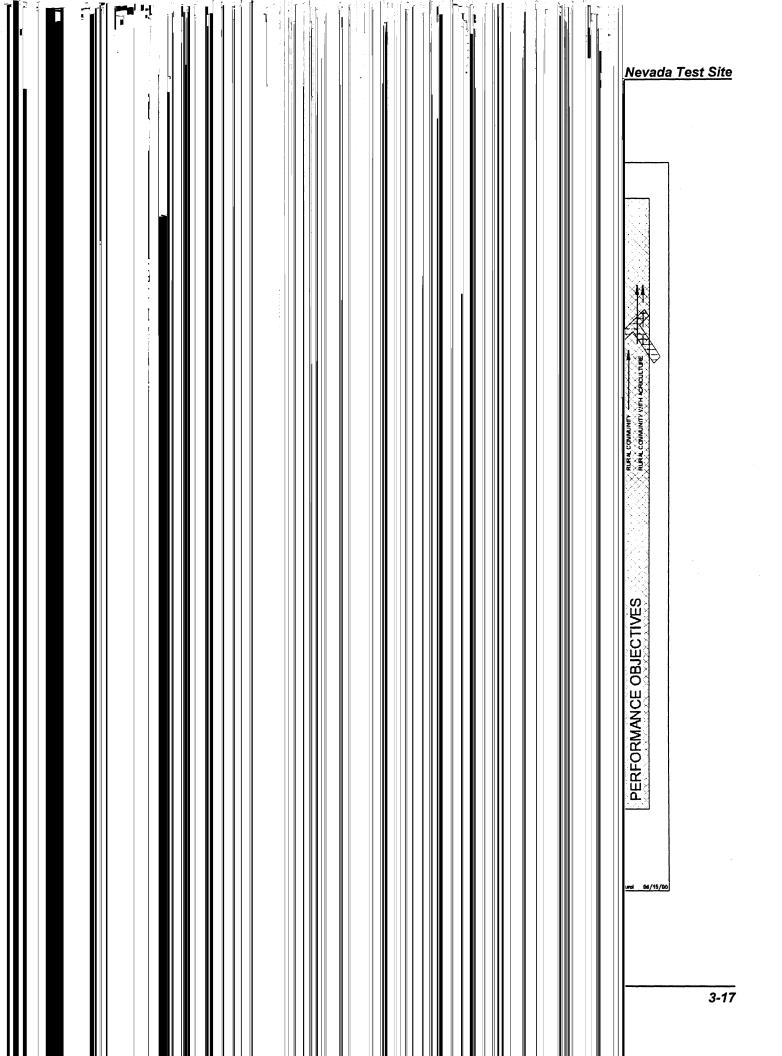
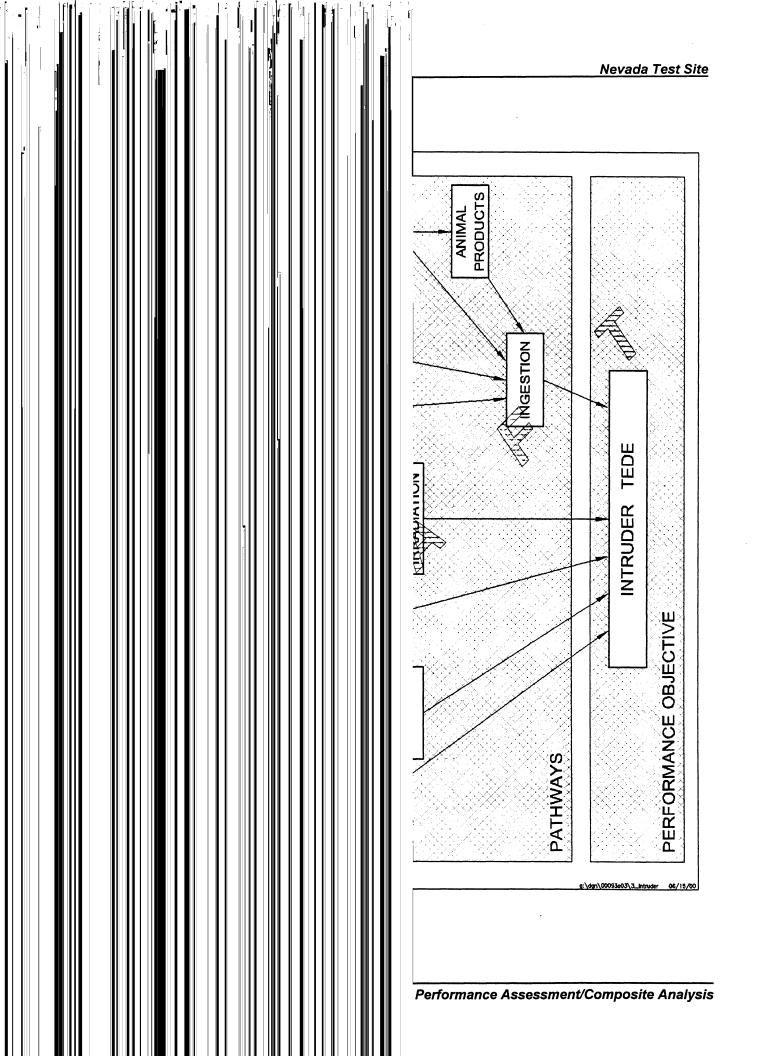


Figure 3.1 Nonvolatile Radionuclide Release Model





nd compared with the result (or base case alts are for the U-3ah/at of the DOUBLE tes the dose from all Area 3 RWMS, except

n exposure to surface r. The conceptual model released from the buried solutes, plant uptake, and nents at the Area 3 eriod. Members of the mmunity 100 m (330 ft) ely that the MOP will griculture is analyzed for ario without agriculture, e through inhalation of volatile radionuclides,

lides that contribute g the screening criteria h, <sup>228</sup>Ra+D, <sup>228</sup>Th+D, Pb+D, <sup>241</sup>Pu, <sup>241</sup>Am, volatile radionuclides are

ttile radionuclides in the it and U-3bh. The out the 1,000-year creasing because of their soil compartment than l, 90Sr, and 137Cs. These ir high plant-soil concented to occur on the

d by radioactive ration of <sup>14</sup>C remains

pliance period
EDE for the
of HTO in air, and
increases slowly after
in shallow soils. The
d predominantly by

be 2e-3 mrem/yr for the 1,000-year es to 4e-3 mrem/yr at -D are the most 1241 Am are the most

icantly less than the liance period, of the United States xcluding radon

E from radionuclides to e objective applies to radon and its exposed to airborne on of volatile

e initial 100 years after centration of HTO in dioactive decay he compliance period nt and are respended m volatile radio-

h/at and 1e-3 at U-3bh -D and <sup>234</sup>U at U-3ah/at

ent/Composite Analysis

#### Nevada Test Site

- increases to
- ?). The important

han the 10 mrem/yr ion of long-lived

remain less than y low at closure at nd its progeny decay. hout the 1,000-year

00-year compliance sity in the compli-: density at U-3ah/at The mean <sup>222</sup>Rn flux 4.2). The maximum ormance objective. nsity, which is

be protected. The ent facilities can be ocal groundwater or local governrements of the DOE 3). The state of strative Code (NAC) s or accumulations Statutes [NRS], ations of radioactive hysically and in no case to exceed Therefore, the PA e is a reasonable uirements for 1,000

psure cap is intact. bssible. Analyses 00 years. Thus, there

# est Site t 1,000 ble to ance on of the ornal meter ough fraction here is nce narios onable is ' ile iance enario apidly t source both nine ap

ion at

Analysis

### levada Test Site

Tionuclides is 2 dispersion

tivity, ratio of le radionuclide TEDE at la plant-soil 1.4), the reference (r = 0.30).

eriod. The al control ensitive to the mrem/yr at s significantly ears after al units, but

Carlo E at U-3ah/at is years after mrem/yr at 250 Table 4.2). years.

nonvolatile DE are to increase to

e appears to be ce objective. ional control.

is investigated je in smallative scenario, increases the *Figure 4.5*). of agriculture. es is relatively insensitive to the occurrence of ence of agriculture decreases at times beyond the increasing time, long-lived actinide progeny such as soil. These nuclides are more important in external han in agricultural pathways.

nunity scenario with agriculture is expected to be most atile radionuclide release model. The TEDE from sitive to the  $^{36}$ Cl plant-soil concentration ratio (r = 0.7) at

igriculture at U-3ah/at is 2e-2 mrem/yr at 250 years after closure (*Table 4.1*). The higher TEDE ty scenario with agriculture is mostly attributable to at the site. The inclusion of agriculture has a smaller mean all-pathways TEDE with agriculture at U-3bh is are and 1e-2 mrem/yr at 1,000 years after closure

re is expected to increase the expected all-pathways o cause the all-pathways performance objective to be tile TEDE is 5e-2 mrem/yr at 250 years and increases to 95th percentile results for U-3bh are slightly lower d value, 15 mrem/yr, occurred at U-3ah/at at 1,000

ture is expected to increase after 1,000 years. At 10,000 community scenario with agriculture is only rem/yr at U-3bh (*Figure 4.5*).

ected to increase the all-pathways TEDE by one order of entory, U-3ah/at. However, all model realizations formance objective. Therefore, there is reasonable mrem/yr all-pathways performance objective, even if the te.

#### nty for the Atmospheric Pathways TEDE

om volatile radionuclides decreases throughout the ecays. The TEDE from nonvolatile radionuclides period as inventory accumulates in surface soils. The outable predominantly to nonvolatile radionuclides for a exposure scenarios, and all disposal units. Therefore, insitive to parameters in the nonvolatile radionuclide

ity analysis is conducted for nine e parameters evaluated are cap und-level radionuclide concen, area of the cap as cracks, and the lost sensitive parameters are the  $^{14}$ C or (r = 0.6). The model indicates lides is most sensitive to the waste etween the disposal site and the

or <sup>14</sup>C, <sup>39</sup>Ar, and <sup>85</sup>Kr because the spheric <sup>3</sup>H concentration is also limited by its vapor pressure in the sensitivity of the TEDE from

of the institutional control period. posal units (Figure 4.6). Therefore, utional control. The TEDE is 30 year compliance period. The to 1e-2 mrem/yr at both disposal

is evaluated by a Monte Carlo entile TEDE was found to be rs (*Table 4.1*). The U-3bh 95th ars and 9e-3 mrem/yr at 1,000 years 'yr, was obtained for both disposal

-3ah/at and U-3bh are less than the tional control periods ranging from bjective. Therefore, it is very likely the 10 mrem/yr performance

ric pathway TEDE is only slightly assumed to increase mass loading, ie amount of time spent outside. The pathways TEDE.

ightly changed by the occurrence of EDE from release of nonvolatiles at

tive to the plant-soil concentration ratios of uranium (r = 0.6) and = U-3ah/at atmospheric pathway TEDE is moderately sensitive to the and the <sup>210</sup>Pb inventory (r = 0.3).

the atmospheric pathways TEDE is evaluated with a Monte Carlo ). The 95th percentile TEDE at U-3ah/at was 2e-3 mrem/yr at 250 e-3 mrem/yr at 1,000 years (*Table 4.1*). The results represent no a slight increase at 1,000 years relative to the scenario without n simulation value of 2e-2 mrem/yr was observed at 1,000 years at r U-3bh are similar to those for U-3ah/at (*Table 4.1*).

IVS TEDE with agriculture is expected to increase slowly beyond TEDE increases to 1e-2 mrem/yr at U-3ah/at 250 years and at 10,000 years (Figure 4.6).

ulture has little impact on the atmospheric pathways dose. The ue, 3e-2 mrem/yr, is significantly less than the 10 mrem/yr. It is very likely that the atmospheric pathway performance objective

## d Uncertainty for 222Rn Flux Density

Rn flux density model is investigated for seven parameters: waste nation coefficient, waste porosity, cap porosity, volumetric water are as cracks, and waste  $\frac{276}{10}$ Ra concentration. Model results are most concentration (r = 0.6), followed by waste emanation coefficient are moderately sensitive to cap porosity (r = 0.3). The results were water content and the fraction of the cap area that is open cracks. ely insensitive to waste bulk density and waste porosity.

<sup>222</sup>Rn flux density estimates is investigated by Monte Carlo seven parameters listed above (Figure 4.12). As the flux density is e compliance period, uncertainty was evaluated at 1,000 years only. ty ranges from 8e-6 to 0.1 pCi/m²/s at 1,000 years (*Figure 4.12*). The Rn flux density distribution is 0.04 pCi/m²/s at 1,000 years flux density ranges from 4e-6 to 0.04 pCi/m²/s at 1,000 years th 95th percentile of the <sup>222</sup>Rn flux density distribution is ears (*Table 4.2*).

expected to continue to increase beyond 1,000 years. The mean flux icrease to approximately 0.5 pCi/m²/s by 10,000 years at U-3ah/at

k density realization within the compliance period is significantly less adard. Therefore, it is very likely that <sup>222</sup>Rn flux density will be less

The

#### Nevada Test Site

the intruder does e of radionuclides

me at both cted for the U-3ah/at intruder nrem/yr by 1,000 which contribute proximately sortance, by percent of the +D, \$\frac{34}{2}\$U, \$\frac{36}{2}\$Cl, and

to be 0.009 redominant source percent at 1,000 ntributed, in , 90 Sr+D, and is contributed, in Am.

nd U-3bh disposal mance objective.

sal site and er creates a 0.15-ms. The intruder is cuttings and to intruder is also

adionuclides with ral release most important ium, plutonium, ource of dose in the

sure as <sup>90</sup>Sr+D and E changes little

Composite Analysis

# Nevada Test Site

yr at 1,000 years and 1,000 years. and <sup>239</sup>Pu remainder is sed by natural the dose by

2 4.14). The 1,000 years. y the intrusion nd 85 percent at

gnificantly less 000 years, The probais very likely ses less than the

erformance, idential scenario neters affecting re scenario.

tdrilling
esident lives at
ces, and
The lack of
ent would
ly to cause

tamination zone ne and depth of previously been activity. The data compilane intruder-

for a typical basement. This is in southern Nevada. If a contrench, septic tank, or swimming have less volume than the sthe dose if the intruder excation depth that could reach re a 0.6 m layer of waste as ott et al., 1998). This increases mrem/yr at U-3bh (Figures 4.13)

the postdrilling intruder scenarion bundance of mobile and predominantly by natural. The postdrilling intruder TEDE inch will be generated by the source term is believed to be acted.

re expected to be sensitive to the rea assumed, 2,500 m<sup>2</sup> area this large would require

at render their results
ncentration ratios or radionuclide
servative assumptions and
urance that the performance

l combined sources of radioactive be less than 100 mrem/yr. If the f options to reduce the potential

ially will be exposed to residual sts, and waste disposed at the ter contaminated by underground e TEDE from three sources of Area 3 RWMS are identified and previously deposited at the site by deposited at the site in the future ucca Flat and Plutonium Valley, a 3 RWMS. Two sources of

Assessment/Composite Analysis

rial are identified for the site: nonvolatile radionuclides dispersed Flat and Plutonium Valley, and volatile and nonvolatile radioe Area 3 RWMS.

or a resident exposed to all of these sources. The resident is the sum of the highest concentration that could result from the NET GZ, Soil Sites in Yucca Flat and Plutonium Valley, and the the highest concentrations do not necessarily occur at the same agle real point of assessment. Rather the results represent a maximum dose that may occur anywhere within the vicinity of the

he MOP from all interactive sources of radioactivity in the vicinity decrease throughout the 1,000-year compliance period (Figure 4.15). om all sources is estimated to be 2 mrem/yr at 250 years ars, the TEDE decreases to 1 mrem/yr. The most significant source is the residual contamination from atmospheric testing at the contributing greater than 80 percent of the TEDE. The TEDE from te at 250 years is attributable predominantly to ingestion of <sup>241</sup>Am in in dose over the first few hundred years after closure is due to the +D and <sup>241</sup>Am. At 1,000 years, the HORNET GZ Soil Site con-TEDE. The remainder is contributed approximately equally by the ucca Flat and Pu Valley Soil Sites. In terms of TEDE received by e Area 3 RWMS, the Area 3 RWMS contributes 17 percent of

# Uncertainty of the Composite Analysis TEDE

nation in the HORNET GZ is the most significant source of the 3. Therefore, parameter sensitivity was investigated for the del only. The sensitivity of the TEDE from the residual soil ated by a Monte Carlo simulation varying 14 radiological x 7) and the HORNET GZ soil concentrations. The 95 percent ORNET GZ soil concentrations is reported to be within a factor of les (McArthur, 1991). The concentrations were assumed to be a the 95th percentile equal to two times the mean. Soil radionuclide cated at zero. Radionuclide concentrations were assumed to be in three groups: activation products (60°Co, 152°Eu, and 154°Eu), fission 137°Cs), and actinides (including progeny).

the TEDE is very sensitive to the fraction of the vegetable intake. The results at 250 years are moderately sensitive to the actinide vegetable intake assumed should be very conservative as the

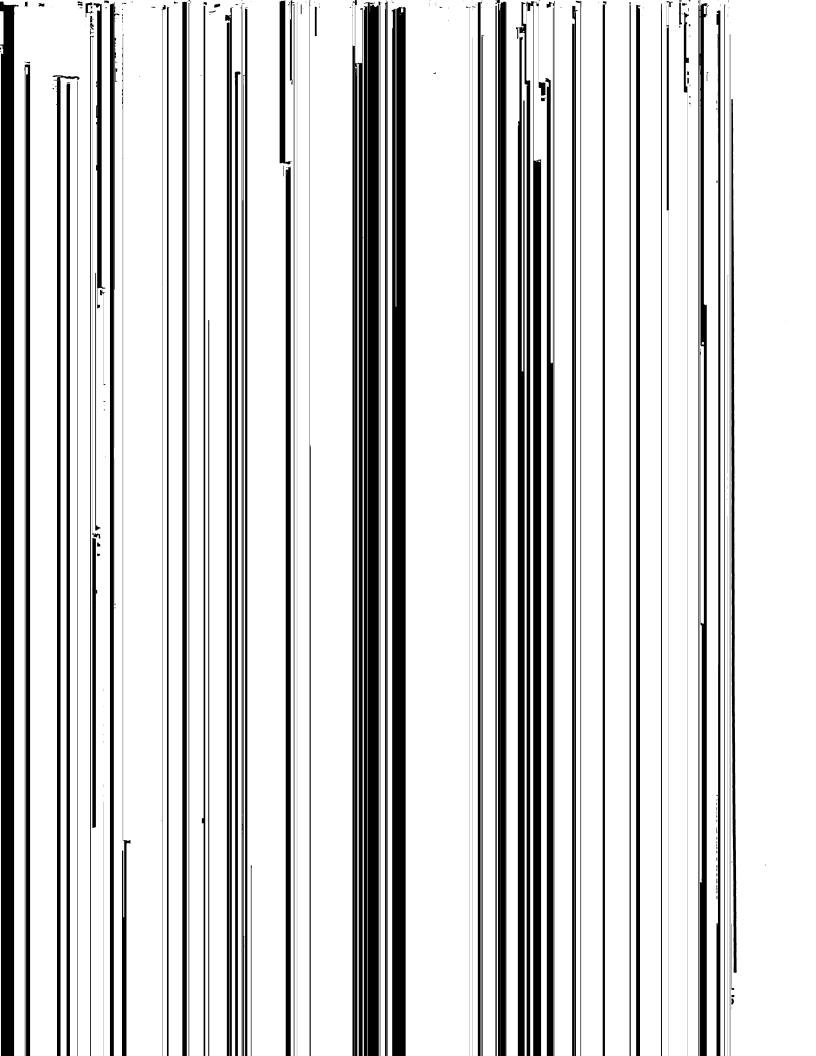
occurrence of any agriculture at this site is a very low probability event. The concentrations of actinides in surface soils at the HORNET GZ are based on *in situ* measurements and soil sampling and are believed to be reasonably accurate.

The results are likely to be very sensitive to assumptions concerning land use or land use controls. The UGTA source is a possible contributor to the dose, which has not been assessed. However the dose from the UGTA source should be zero as long as land use controls affecting groundwater access are effective. The land use assumed for Yucca Flat represents a conservative bounding estimate. The TEDE may increase in the period of institutional control is shorter than 250 years. All credible alternative land uses would most likely result in much lower doses. The mean TEDE at 100 years is estimated to be only 4 mrem/yr, still significantly less than the 30 mrem/yr dose constraint. Conservative assumptions in the land use scenario include:

- There is no remediation of Soil Sites in Yucca Flat or Plutonium Valley.
- There is no access control after 250 years. The MOP is assumed to have access to Yucca Flat.
- The MOP constructs a permanent residence in Yucca Flat in the vicinity of the site.
- The MOP engages in noncommercial agriculture.

Parameter uncertainty in the TEDE from the residual soil contamination area is investigated by Monte Carlo simulation, varying the parameters considered in the sensitivity analysis above (Figure 4.16). At 250 years, the 95th percentile TEDE is estimated to be 5 mrem/yr. The maximum simulated value was 8 mrem/yr Therefore, there is a very high probability using a conservative bounding land use option that the TEDE is less than the 30 mrem/yr options analysis dose limit. The 95th percentile TEDE decreases to 2 mrem/yr by 1,000 years. The maximum simulated value at 1,000 years was 3 mrem/yr. All realizations at 1,000 years are below the 30 mrem/yr limit triggering the options analysis. All results are significantly less than the 100 mrem/yr performance objective. There is reasonable assurance that the CA performance objectives can be met assuming that access to Yucca Flat groundwater is restricted.



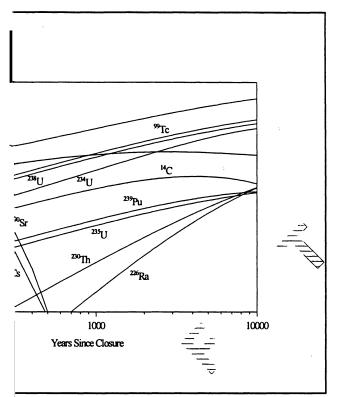


# bh Disposal Units

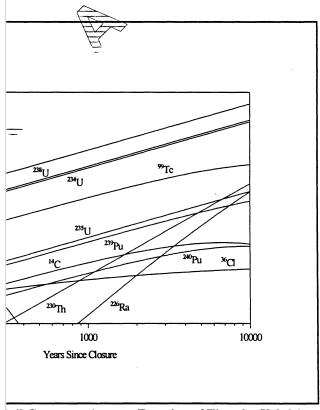
s Units	Time During Compliance Period When Maximum Occurred
mrem/yr	1,000
mrem/yr	1,000
mrem/yr	1,000
mrem/yr	250

olic in the Vicinity of the Area 3

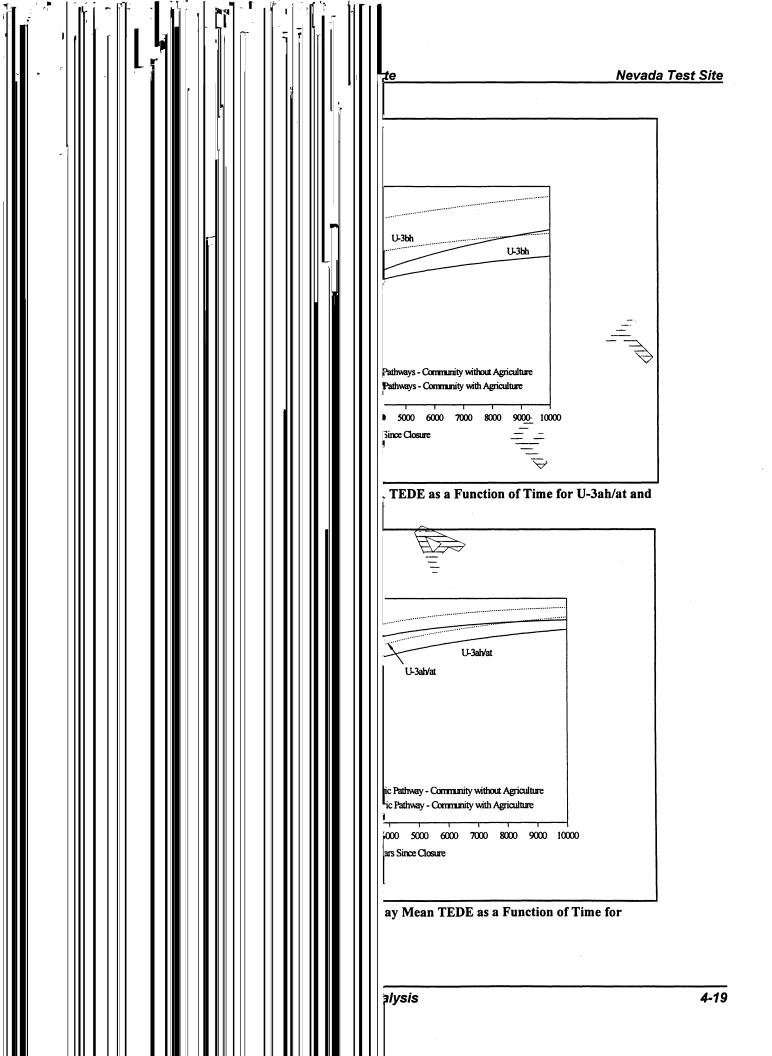
Sure 1,000 Years After Closure	
	0.2
	0.2
	0.03
	0.01
	1



w Soil Concentration as a Function of Time for



soil Concentration as a Function of Time for U-3ah/at



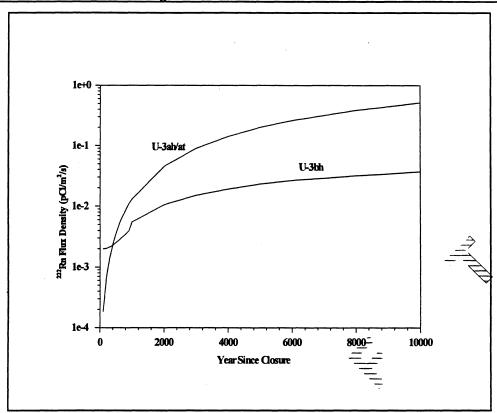


Figure 4.7 Mean <sup>222</sup>Rn Flux Density as a Function of Time for U-3ah/at and U-3bh

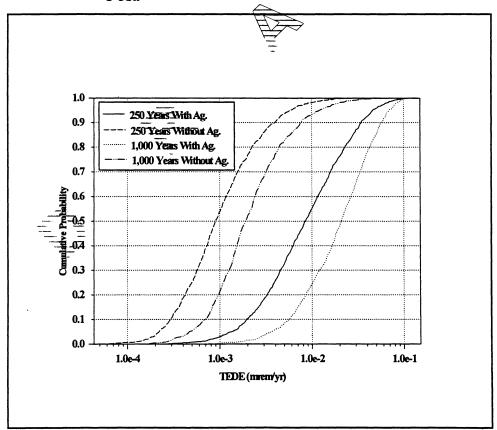
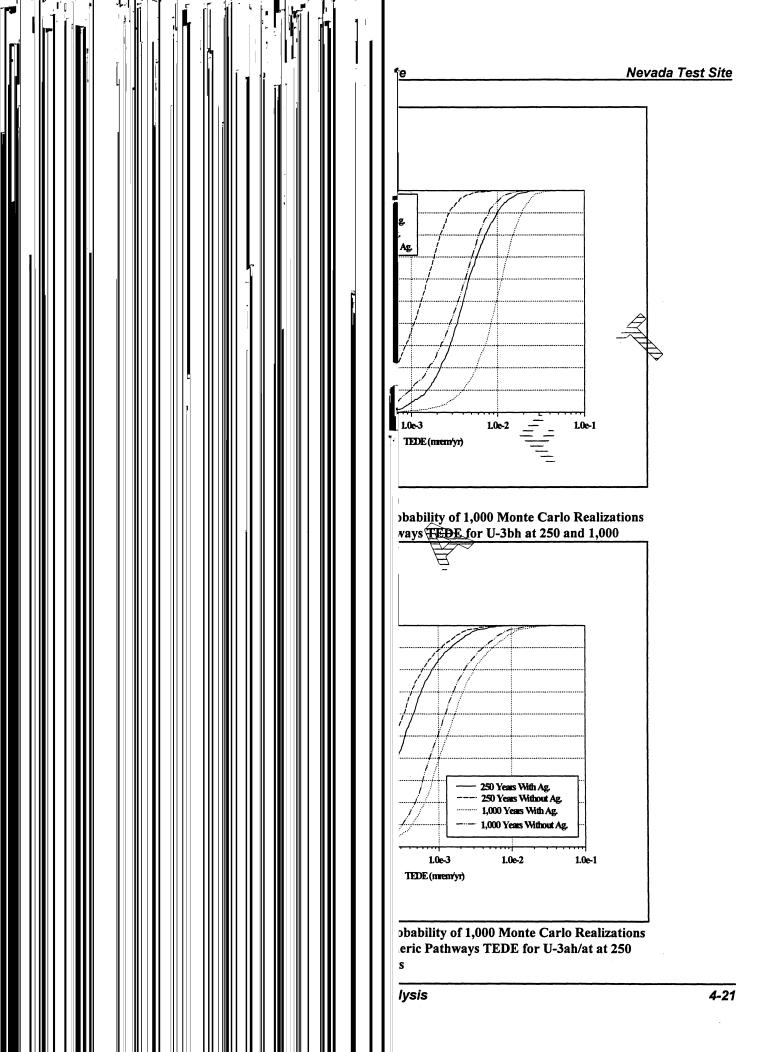


Figure 4.8 Cumulative Probability of 1,000 Monte Carlo Realizations of the All-Pathways TEDE for U-3ah/at at 250 and 1,000 Years



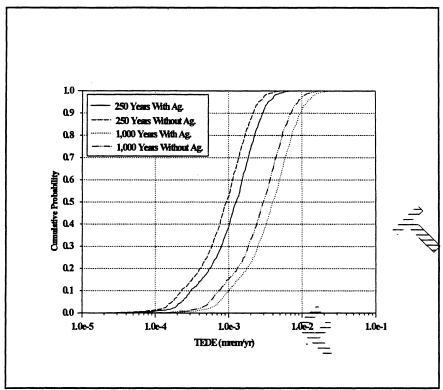


Figure 4.11 Cumulative Probability of 1,000 Monte Carlo Realizations of the Atmospheric Pathways TEDE for U-3bh at 250 and

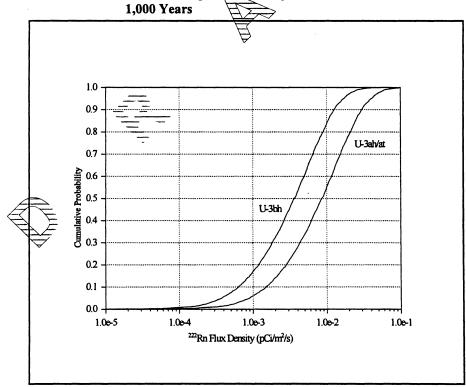
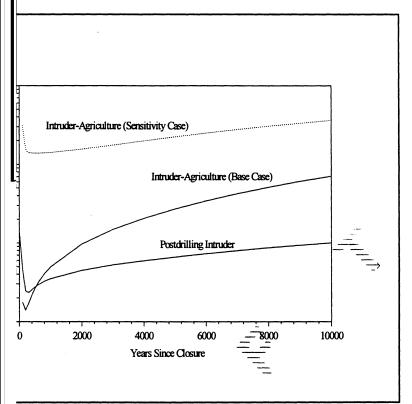
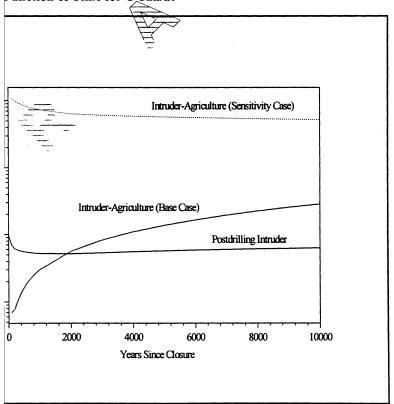


Figure 4.12 Cumulative Probability of 3,000 Monte Carlo Realizations of <sup>222</sup>Rn Flux Density for U-3ah/at and U-3bh at 1,000 Years





Intruder-Agriculture and Postdrilling Intruder TEDE as a Function of Time for U-3ah/at



Intruder-Agriculture and Postdrilling Intruder TEDE as a Function of Time at U-3bh

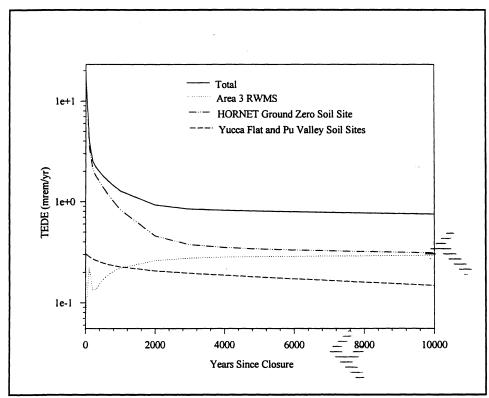


Figure 4.15 Composite Analysis TEDE as a Function of Time for a Resident 100 m from the Area 3 RWMS Boundary

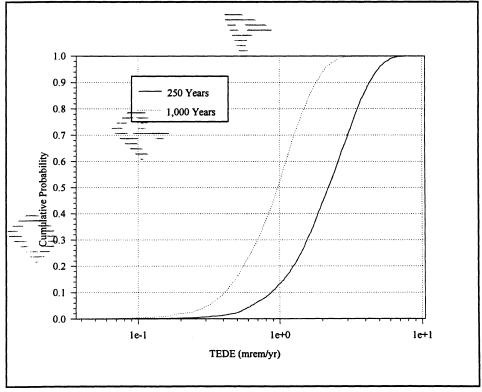


Figure 4.16 Cumulative Probability of 3,000 Monte Carlo Realizations of the Composite Analysis TEDE Estimated for the HORNET Ground Zero Soil Site at 250 and 1,000 Years

### Nevada Test Site

esults of their te acceptance

## with

he U-3ah/at and TEDE or mean ponding perforor all uncertainty dence that the

Inuclides may be of run-on in a formance is iod of at least ward pathway

/at and U-3bh is n 100 to 300 radionuclides DP in the he 100-m (330-ft) y equal at both t U-3ah/at and to EDE increases to

the compliance posal unit at indary

nce period. The unit at 1,000

nvironment and all is returned to n to the aquifer.

alternative scenario, where run-on floods in a subsided disposal unit, indicates ting water does not reach the aquifer in 1,000 years.

the Area 3 RWMS appear to meet ALARA requirements. Assuming the gross ternative disposal options are equivalent, costs at the Area 3 RWMS are lisposal costs and health detriment costs. The health detriment costs are negligible because of the low doses projected and the low population densities refore, there are no more costly disposal options that would optimize

imated for hypothetical intruders for two chronic intruder scenarios was a small performance objectives (*Table 5.1*). The highest TEDE, 0.06 mrem/yr, was a postdrilling intruder scenario at U-3bh, 250 years after closure. Because sments have shown that the doses for acute scenarios are less than those for ios, compliance with the acute scenario performance objective is assumed.

for the Area 3 RWMS are less than the performance objective limits. uncertainty provides reasonable assurance that the performance objective can stal uncertainty in the results can be partitioned into model uncertainty, tainty, and parameter uncertainty. Although model uncertainty has not been slicitly, the many conservative assumptions within the models render their ervative bounding results. Conservative assumptions included in the models

atile inventory is assumed to be incomediately available for release and containers and waste forms are not assumed to retard radionuclide release. It is at the release will be retarded by containers and stable waste forms for some I the period of institutional control.

radionuclide inventory is assumed to be released immediately to the air-filled of the waste. The total inventory of <sup>14</sup>C is assumed to be released as a gas to space. It is probable that some fraction of the <sup>14</sup>C source term will be bound matrix and released slowly over many years. Under the model assumptions, ventory of <sup>14</sup>C diffuses out of the site in a single year. No more conservative ase model is possible.

atile radionuclide soil concentration at the MOP's residence is assumed to be concentration of soil above the disposal unit. Dilution is expected to occur as ination is transported from the disposal site to the off-site residence by wind, siota.

sumed to be uniformly active to a depth of 4.5 m (15 ft) in the alluvium. This -m (4.9-ft) layer of waste available for biological transport. Most data indicate

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3bh ceedlux ,000

m yr )E to

### Nevada Test Site

if land use and nuclear

idual radioactive in the Area 3 ter closure. o cause approxie Area 3 RWMS

sults should be coreasing over r, there is a high f the period of 1/yr, and the low RA.

esign is described

entration limits e period. Waste urrent 1,000-year

use contamination cur before 1,000 nation of the uestionable for reasonable occurs. Second, vaste stabilization significance of alt to assess. The ctive materials current practice is nt possible and to MS inventory practices appear

composite Analysis

## vada Test Site

m cap is I site I control t closure. A I sion and to ed by waste

des from the nuclide gle year. cness and ause the a year. The er, the be exceeded

ults indicate ection cannot rom release population

ty is

ill occur at ver will lat.
It runoff to int to the ensitive to nay be slower rties of the cal and spatial would neld at would the waste

data have been reported, it might be measurements to confirm that the NTS. Parameters without sitects, colony densities, burrow excava-

. Site-specific plant-soil concentration er has a naturally high variability. It is ignificantly reduced with a few site-be reduced by identifying plant-soil icable to the plant species and soils





nce Assessment Results With the Performance Objectives

ctive	Maximum Result in the Compliance Period
Groundwater, Soil, Plants,	4e-3 mrem/yr
ling Rn) Less than 10	4e-3 mrem/yr
	0.01 pCi/m²/yr
	No Release to Aquifer in 1,000 Years
h/yr	0.06 mrem/yr
	< 0.04 mrem/yr





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edures of the Bechtel Nevada Performance 96c). The PAMP implements the requireince Rule for Nuclear Facilities (DOE, jurance Order" (DOE, 1991). The PAMP rogram, Training and Qualification, ent, Management Assessment, Documents and t, Inspection and Acceptance Testing, and

and Records, Work Processes, and Design ortant quality commitments in the PAMP

ents shall be prepared, reviewed, approved, becify requirements, or establish design.

ware controls should include verification and

originate or verify design solutions during tatus of the code validation shall be identified

naintained to support the basis and output of s appropriate, the design input basis docutheir revisions, computer programs, analyses,

mal document process to establish that the ill be fit for the intended use. The extent and sed on a graded approach and depend on the ice to project success.

be the process of assuring that a computer or system being modeled. Because perforccur over tens to thousands of years, validation assessment. Computer software verification is r software correctly performs a specified are was found to have been adequately verified packages, an installation verification was are can reproduce results provided by the

ysis 6-1

red in BN Procedure L-F11.003, procedure describes the responsiering calculations used in the PA. The

put data, and calculation results.
mpleted engineering calculations.

mputer software and hardware used, by a qualified and independent ned for future review.

nd Verification

efore use. Verification of computer

tet of differential equations which te layers into the two closure cap hand calculation was performed to g to the *Engineering Analysis*/ the fourth-order Runge-Kutta method andom number-generating algorithms as assured that the random number utions.

nalytical solution to a oneemented with an Excel<sup>o</sup> spreadsheet. ne Crystal Ball package (Version 4.0) ified by hand calculation using the

RC Regulatory Guide 3.64 (NRC, d with an Excel<sup>©</sup> spreadsheet. Monte tal Ball package (Version 4.0) ompared with results from the (Version 1.2) (NRC, 1989). The results for all test cases. The paring its results with the results for

nethods of Kennedy and Strenge (1992). The this clasheet. Monte Carlo uncertainty analyses are in 4.0) (Decisioneering, 1996). The spreadth RESRAD (Version 5.61) (Yu et al., 1993) veloped and -supported code designed to dioactive materials. The spreadsheet is also griculture scenario. Results of the pendix 7.

late the radioactive ingrowth and decay of is a computer code developed by Oak Ridge ildup, processing, and decay of radioactive is verified by comparing its results to results analytical solutions to the Bateman

mospheric dispersion from multiple sources ped and verified by the EPA (EPA, 1995a,b). paring the results of sample problems with



h the VS2DT code. The VS2DT code was tal., 1993). An installation verification was provided with the code, and duplicating

n evaluated by comparing modeling results sidered true model validation. Computer computer model is a correct representation of n is carried out by comparing calculations its. True validation requires comparing observations (Seitz et al., 1990). Criteria for r to the experiment. Defensible validation of idditional field experiments and analysis of

osses several problems in general and several he conceptual model of the disposal site after it the site. The entire inventory expected for

sis 6-3

nermore, the site has not been closed as assumed in nits have no closure cap. Others have operational cknesses than assumed in the conceptual model. ded and are not vegetated. Therefore, the current ses, degrees of integrity, water contents, primary in assumed in the performance assessment conceptual

phasizes the long-term performance of the site and ortant in the near term. Radionuclides with half-lives the analysis. The conceptual model assumes there at waste forms do not retard radionuclide release. In as likely control release from the site. The Area 3 use the expected inventory is small and residual ic testing can readily be detected at the site. The the nonvolatile radionuclide release model are le detection limits. Computer model validation is a design and execution of specific experimental attempt has been made to validate the models used in

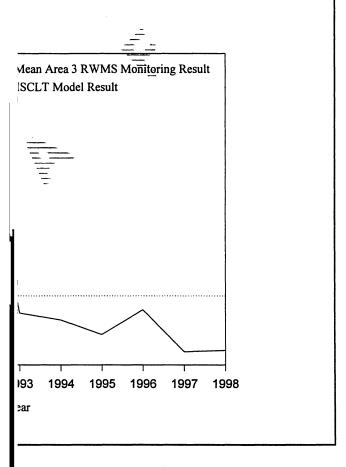
nt models are considered to be conservative. Some ared with performance assessment results to confirm els. It should be remembered that the performance natch the actual conditions of the environmental

and detected at the Area 3 RWMS. Airborne thought to be resuspended from atmospheric testing  $\Gamma$  model was used to estimate the airborne concensist resulting from resuspension of plutonium from Valley. This modeling was performed as part of the 1 case should be nearly equivalent to currently 1 le last 11 years of monitoring data indicate that there 1 ng data and modeling results (Figure 6.1). The mean 1 an measured airborne  $^{239,240}$ Pu concentration is  $20 \pm 10^{-17}$  Ci/m³. The ISCLT model uses 1 plume model. These models have been validated 1 to give reasonable approximations of long-term

e for the Area 3 RWMS is two years of airborne <sup>3</sup>H ared with the airborne <sup>3</sup>H estimates from the volatile performed as part of the performance assessment

not match the current monitoring conditions. ant source of airborne <sup>3</sup>H in the area, but the on, waste form, and container condition are seessment. The mean <sup>3</sup>H monitoring result for odeling results range from 6 × 10<sup>-9</sup> Ci/m<sup>3</sup> at odeling results are nearly 10,000 times the s are very conservative in the near term. The etermined.





asurement Results for 239,240Pu at the Area 3 RWMS

alysis 6-5

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# estigators

ysics, Georgia Institute of Technology – 1996 I Fishery Science, University of Washington – 1984 Jniversity of New Hampshire – 1981

s a Certified Health Physicist with ten years of experience in onitoring and waste management. As the lead health physicist for sisted with the nonvolatile radionuclide release model and lattle radionuclide modeling, radon release modeling, and all sments.



ineering, Iowa State University, Ames – 1971 ineering, Iowa State University, Ames – 1969

egistered Civil Engineer/hydrologist with 25 years of experience in d engineering hydraulies/hydrology. He completed pre-doctoral e Civil Engineering Department at Stanford University during 1973-1 emphasis on simulation and stochastic processes in hydrology. He raulics/Hydrology/Modeling group in the Geotechnical and ering Services section at Bechtel's Oak Ridge office. The group y service to environmental restoration and waste management e water and groundwater hydrology, fate and transport modeling, 1 geostatistics. His recent project experience includes flow and 1 g for the siting and licensing of the low-level radioactive waste n Nebraska for the Central Interstate Compact, hydrologic 1 flow and transport modeling for risk assessments at several sites of 1 y Used Sites Remedial Action Program project, and the risk 1 nydrologic modeling for the Oak Ridge National Laboratory 1 gation/Feasibility Study project.

as the technical lead for the PA/CA. He performed the transport nonvolatile radionuclides, air modeling for the CA, flood hydrology, one transport calculations.

## Sully

Soil Science, University of California, Davis – 1984 Atmospheric Science, University of California, Davis – 1979 Physics, University of Montana, Missoula – 1976

ael Sully is a hydrologist contributing to site characterization of flow, transport rties, and field investigations of soil-plant-water interactions. He served as an ant professor at the Department of Hydrology and Water Resources at the rsity of Arizona, and as an experimental scientist at CSIRO Division of onmental Mechanics in Canberra, Australia. He summarized all hydrologic site cterization data, developed the hydrologic conceptual model, and assisted in and transport modeling.

#### E. Barker

Statistics, Florida State University – 1979 Statistics, Florida State University – 1976 Mathematics, University of Kentucky – 1975

ence Barker joined Reynolds Electrical & Engineering Co., Inc., in 1989 and nued with BN in 1996 as the Principal Applied Statistician. His statistical tise has contributed to the solution of many problems in waste management, onmental monitoring, and site characterization. He was on the faculty of the timent of Mathematics at the University of Tennessee for five years. His work cently appeared in Soil Science Society American Journal, as well as numerous publications. Lawrence Barker acted as an editor for the performance sment and assisted in sensitivity and uncertainty analyses.

#### 'awlinson

Geology, University of Alaska – 1990 Geology, University of Alaska – 1979 Geology, California State University, Long Beach – 1974 Liberal Arts, Los Angeles Harbor College – 1972

uart Rawlinson is a Certified Geologist with the American Institute of ssional Geologists, a Certified Geologist in Alaska, and a Certified onmental Manager in Nevada. He has 20 years' experience in development, gement, and implementation of geological and related technical studies for site eterization, performance assessment; and assessments of natural resources and al hazards. Dr. Rawlinson has been with BN and predecessor contractors since using his expertise in support of the DOE/NV Office of Environmental gement. He previously worked for the State of Alaska Division of Geological ecophysical Surveys, and for the Outer Continental Shelf Environmental

University of Alaska. Dr. Rawlinson contributed summary sections, and served as editor of the

Idaho – 1983 nces, Pennsylvania State University – 1978 Midland College, Texas – 1993

nd has been the U.S. DOE/NV Project Manager for the Characterization in the Waste Management served as the technical lead for the expert panel bility of inadvertent human intrusion into radioactive e. She has over 16 years of consulting and but DOE and the U.S. EPA in environmental site deling and monitoring as well as waste

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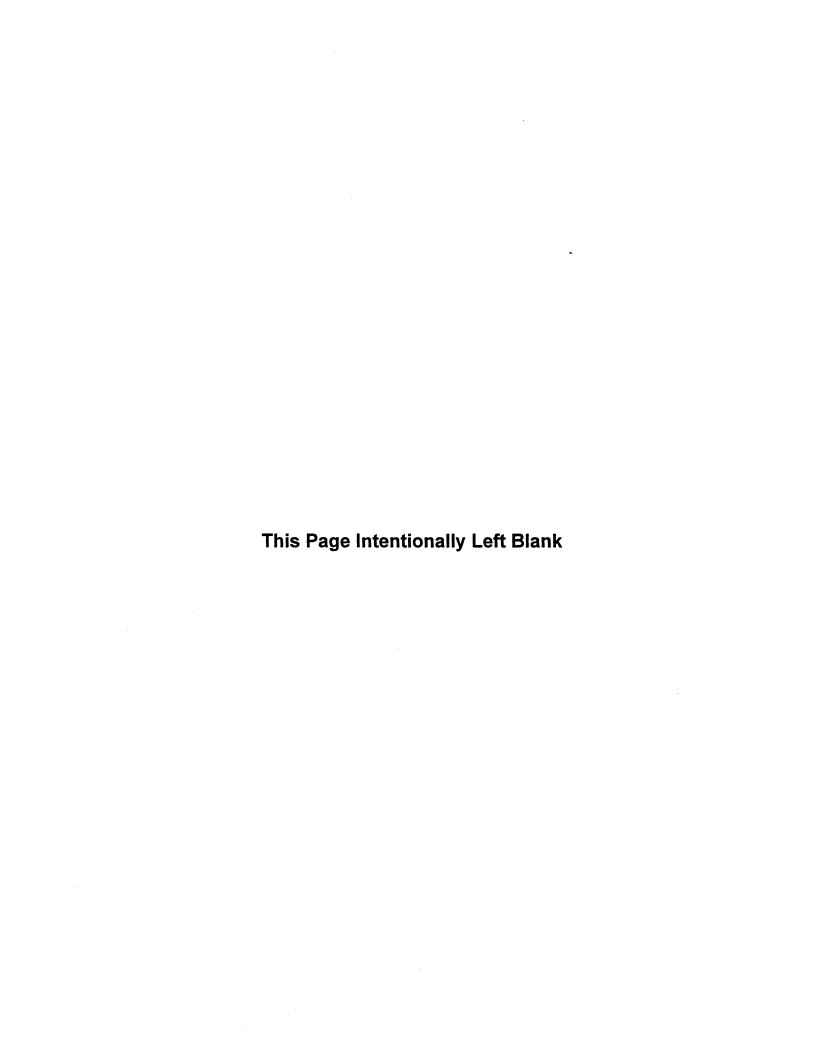
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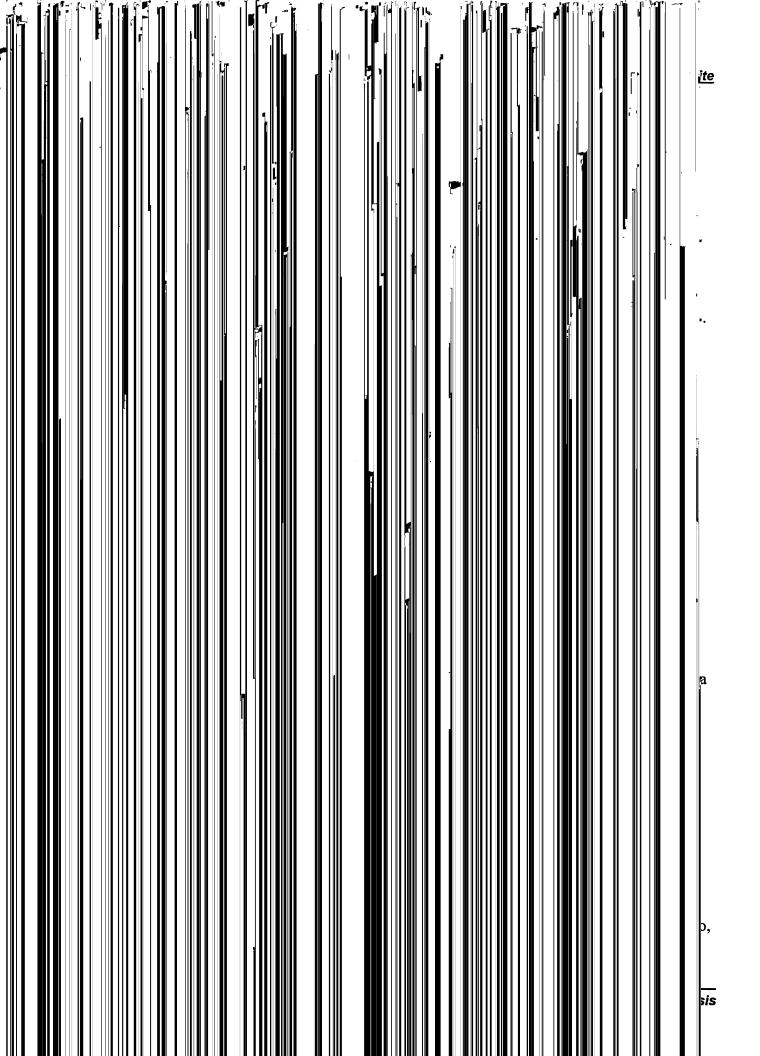
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# Appendix 1 Characterization of the Vadose Zone

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confining unit ctive Waste Management imately 305 to 460 meters ifer ranges from approxif confining unit is at The water table occurs in face.

er devices in the early ground surface in shafts device, pressures and the gas pressure dissipated oof of the cavity collapsed sucer-like subsidence crater he void propagates is its within the Area 3 to (400 to 580 ft) in 1996).

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s was begun by were drilled Boreholes vertically from ater floor. The ollapse zone he charac-Core samples and geologic neasurement of acteristics; and nclusion of the man n the collapse nes below two ese projects the nearmapping and ons. Results of

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## Nevada Test Site

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y Lake meteorology wind speed of Predominating winds corded in 1996 at the Ire A1.9. In 1996, 48 mph). Monthly Area 3 RWMS rom 8.1 to 12.8 m/s 16 to 25 mph) at a est in winter.

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The basins of the NTS are extremely arid and are characterized by very low humidity, particularly during summer. Daily average relative humidity at the RWMS during 1996 is shown in Figure A1.11. Daily average values ranged from a minimum of 11 percent during spring and summer months to a maximum of 94 percent during December.

In the basins of the NTS, evaporation occurs only at potential rates following significant precipitation events. Evaporation from soil occurs in two stages (Jury *et al.*, 1991). Following a precipitation event, the surface of the soil is wet and the rate of evaporation is limited by the meteorological conditions. During this constant-rate stage, water can be supplied to the surface from the soil below at a rate corresponding to the maximum rate of loss determined by the available energy, wind speed, and relative humidity. As the soil dries, the resistance to the movement of water to the surface layer increases and the rate of evaporation progressively decreases. This falling rate-stage of evaporation is controlled by the soil properties.

Evaporation from plants, referred to as transpiration, is further influenced by physical and morphological characteristics of the plant canopy (Campbell, 1986). Evapotranspiration is the combined loss of water due to evaporation from the soil surface and transpiration from the plants.

Actual evapotranspiration and bare soil evaporation were measured using precision weighing lysimeters in Frenchman Flat, an alluvial basin on the NTS 22.4 km (13.9 mi) from the Area 3 RWMS. These lysimeters each consistent a soil tank, 2 m by 4 m (6.6 ft by 13.1 ft) in cross-section and 2 m (6.6 ft) deep, supported on a sensitive scale, and equipped with electronic load cells and data acquisition systems for the continuous measurement of evapotranspiration. One lysimeter has been planted with native plant species in the approximate density of the surrounding desert landscape, while the second lysimeter has a bare soil surface. Figure A1.12 depicts the amount of water stored in each lysimeter and recorded precipitation from December 1994 through April 1997. The amount of stored water increased following precipitation events during the winter of 1994-1995. Beginning in April 1995, the bare soil lysimeter shows a gradual loss in water caused by evaporation. A more rapid loss is seen in the vegetated lysimeter as the plants began to transpire in the spring. These results demonstrate the large influence of plants on water movement in the upper few meters of the allowium. In April, May, June, and July 1995, transpiration estimated from the difference between bare and vegetated lysimeter measurements was 60, 67, 61, and 51 percent, respectively, of the total water loss for each month.

Seasonal changes in temperature at the land surface create vertical temperature gradients in the alluvium. Daily average temperatures at 10-cm (4-in.) and 170-cm (67-in.) depths for Frenchman Flat are shown in Figure A1.13. Temperature gradients induce the movement of water vapor from warm soil to cold soil. On a seasonal basis, these gradients lead to the transport of water vapor upward during the winter and downward during the summer.

## Nevada Test Site

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rea 3 8 m des J1a.101 rater The average particle size fractions for the <2-mm (<0.08-in.) fine-percent sand, 16.2 percent silt, and 10.4 percent clay. Compared with values shown in *Table A1.1* of 80.6 percent sand, 10.1 percent silt, nese results from 296 m (971 ft) represent a trend toward an increase of lepth. Water content samples taken ranged from 0.07 to 0.23 m³/m³, a ea 3 characterization samples. Volumetric water contents of samples roximately 300 m (984 ft) in emplacement borehole U-3at were [1996) to average 0.23 m³/m³.

the alluvial deposits are approximately 305 to 457 m (1,000 to top of the underlying tuff confining unit is at depths between 670 m (1,440 to 2,200 ft). The water table occurs in the tuff units 1,614 ft) below the ground surface. All of the tuff aguifer and fining unit may be unsaturated under the Area 3 RWMS. However, vely proved or disproved because of the lack of deep drillhole data at it to the facility.

elded tuff and is characterized by high fracture permeability. ated hydraulic conductivity of seven welded tuff samples ranged from 10 to 5.61 ft/day) (Rehfeldt *et al.*, 1995). The tuff confining unit is led, nonwelded tuff that has been altered to zeolite minerals by with groundwater, resulting in decreased rock permeability. Measure-raulic conductivity of 34 zeolitized tuff samples ranged from 2 x 10<sup>-6</sup> to 0.07 ft/day) (Winograd and Thordarson, 1975).

#### Zones

apse zone below a crater is uncertain. Two idealized geometries have terature. The first is the inverted cone model, with the boundaries of ding unwards from the cavity to the edges of the crater. With this um within the rim of the crater would be in the collapse zone. The nodel which prescribes the boundaries of the collapse zone as a is of the cavity extending upward to the land surface. Because this se zone radius which may be less that the crater radius, portions of the the crater surface but not within the collapse zone. In reality, the spherical and the collapse zone boundaries are influenced by formation.

e of waste in U-3ax/bl and U-3ah/at, these craters could not be the surface. Angle drilling was employed to reach the collapse zone at 1g the waste. Four angled boreholes provided samples from the collapse zones below U-3bl and U-3at. These samples ranged in depth o 486 ft). Because of the uncertainty in defining collapse zone med that samples from the angle boreholes above 30 m (98 ft) were imples from below this depth were either from the collapse zone or ence of the crater.

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w a waste cell was using VS2DT, a prous media (Lappala modeled using two er et al., 1992; Pohll tle, yet distinct characterization were taken from the ne waste was assumed intent of 0.15 m<sup>3</sup>/m<sup>3</sup>. el runs simulated 100

## Nevada Test Site

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I significantly different is profile scenario, a 100 years. For the ayers, there was no in the profile. These atter content in portions occur after closure ever, vertical fluxes

analysis of 95 cores t) to approximately low U-3at and U-3bl

sity, and particle size a Table A1.1. No ge particle density and e land surface. The surface in the U-3bh

y and the aulic characteristics collapse zone samples in U-3bh collapse zone, kimately half that of sters for the U-3at and those for the U-3bh

nes is shown in 1<sup>3</sup>, while individual samples imply ess permeable horizons where downward flow of water is impeded, up of water content, giving an appearance of perched water. Water really increased with depth. The increased water content at these rent recharge, but is a remnant of recharge during a past cooler, wetter his is seen in the stable isotope ratios from the U-3at and U-3bl led mean concentrations for winter precipitation in Frenchman Flat 2.5 % and -93 % for δ<sup>18</sup>O and δD, respectively (Tyler *et al.*, 1996). epresent precipitation under cooler temperatures. Stable isotope ollapse zone samples taken below 66 m (217 ft) from the land surface .23. The weighted winter mean concentrations are indicated by the compositions of these samples are more depleted than weighted mean itation alone. These results indicate that the pore water found in the see zones below 66 m (217 ft) must have infiltrated under cooler, past

all with depth for the U-3at and U-3bl collapse zones is shown in h variable, matric potential tended to increase with depth. Average I from -1.7 MPa at a depth of 42.5 m (150 ft) to -0.47 MPa at 108 m it of matric potential measurable with the water activity meter is otentials of individual samples ranged from -2.6 to greater than th of 120 m (394 ft), matric potentials were consistently greater than er contents between 120 and 148 m (394 and 486 ft) ranged from 0.13

shown with depth in Figure A1.24. From a depth of 50 m (164 ft) to 394 ft), there is little variation in total potential with depth. A constant h implies that pore water is static or nonmoving in this zone. Below potentials were consistently greater than -0.4 MPa to the deepest (486 ft). It is reasonable to assume that drainage of the profile nent of drier climatic conditions at the surface leads to uniform matric on from below 120 m (394 ft) to the water table. Flow under these o gravity, and the flux is equal to the hydraulic conductivity at the t. Using mean values of porosity,  $K_s$ , n, and  $\theta_r$  for the U-3at and om Table A1.1 with the highest average water content (Figure A1.15) talem conductivity model gives a vertical flux of 0.35 m/yr.

on concerning characteristics and processes at greater depths in The information from the U1a.101 drift in the Lyner Complex above provides some insight into characteristics of alluvium as deep e only records specific to a collapse zone in Area 3 RWMS are s for U-3at. Plannerer (1996) noted that the postshot drilling records circulation of drilling mud occurred in all three postshot boreholes at circulation in U-3at-PS#1 was first reported at 231.6 m (760 ft), in (770 ft), and in U-3at-PS#3 at a vertical depth of 246.9 m (810 ft).

## Nevada Test Site

table to a 246.9 m (760 and high-permeability

aracteristics other consideras combine to An important of the climate and d by the presence gic setting could d, by analogy with and the subsequent the collapse zone ter on the surface gher water le (Tyler et al., ables, hollow drill und surface may groundwater table.

roperties in pse zones to a sults indicate that ability.

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model were determined using the Soil Conservation Service nethod. A CN value of 70 (corresponding to sandy and loamy-conditions which are typical of the drainage area) was used to off from the 170-hectare (ha) (420-acre [ac]) drainage area p. The SCS dimensionless unit hydrograph procedure was used, to translate the net rainfall hydrograph into the flood hydrograph en integrated to derive the flood volumes. Flood volumes and the Is (probability) were plotted on log-probability paper to derive the ationship. The 100-year flood volume was 86 acre-feet (21,216 I volumes for the 200-, 500-, and 1,000-year frequencies were 49,300 m³, respectively.

U-3ah/at is 34,820 m<sup>2</sup>, with a width of about 96 m (315 ft) and a 1. The bottom width of the subsided cap would be 1 12 m (367 ft), lepth of 14 m (46 ft) (Obi *et al.*, 1996). A depth-volume relation-sided cap. The maximum ponding depths corresponding to 100-, flood volumes were 2, 2.5, 3.2, and 4 m (6, 8, 10, and 13 ft),

## ow Modeling

in of flood waters through the fully subsided U-3ah/at waste cell T, a computer code for simulating variably saturated, single-a (Lappala et al., 1993; Healy, 1990). The simulation was sional geometry. The waste cell was assumed to be 15 m (49 ft) water table was assumed to be 477 m (1,600 ft) from the bottom of ide spacing was set to 1 m (3 ft). Initial water content was hroughout the profile; this was the approximate mean value of all the Area 3 borehole characterization data (Schmeltzer et al., 5a, 5, 1997). One set of van Genuchten hydraulic parameters was a shorehole characterization. The log-means of the borehole data raulic conductivity and alpha, and means of the borehole data r content and the n parameter. These values are summarized in

van Genuchten Hydraulic Para	ameters
ated conductivity (ln m/s)	-11.705
ı (ln cm <sup>-1</sup> )	-4.183
al water content (m³/m³)	0.120
ed water content (m³/m³)	0.373
	1.684

n of 4 m (13 ft) of flood water into the subsided waste cell was hours of infiltration, and using the output file from that

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which implements the U.S. Department of Energy's (DOE's) The distribution coefficients are provided for sand, loam, clay, distribution coefficients for sand were used in this analysis.

I time of radionuclides to the water table by making several

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requency precipitation events ponds in the subsided unit, and leads to recharge to the groundwater.

is assumed to be a steady-state flux rate used to estimate

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distribution coefficient of radionuclides, assuming the soil

have a high moisture content.

ble exceeds 1,000 years for all of the radionuclides. Tritium 10 years, and technetium in 2,160 years; all other radionuclides of 10,000 years. Therefore, the groundwater pathway is not or the performance assessment or for the composite analysis.

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Nevada Test Site d edition. Data From the 718-003. U.S. ce Assessment t Site, Nye rgy, Nevada J. Miller, n Great Basin,
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<u>ment</u>	Site		 Nevada Test Site
v.o 4.0	1.68	1.18 0.344 0.052	
9.3	-11.7	-4.18 1.68 0.12	
0.0 4.4	1.74	1.06 0.337 0.041	
5.01 9.7	-12.1	-4.42 1.74 0.135	
7.3 2.6	1.60	0.89 0.274 0.033	
10.2 8.5	-11.2	142 1.74 0.132	
() 4.2 4.3	1.45	1.37 0.368 0.057	
7.3 8.9	-11.4	-3.34 1.49 0.067	
Silt Fraction [wt %] Clay Fraction [wt %]	In Saturated Conductivity [In (m s <sup>1</sup> )]	Van Genuchten Parameters	

site Analysis

Silt Fraction [wt %] Clay Fraction [wt %]

# Duration-Frequency Relationship for the Area 3 RWMS

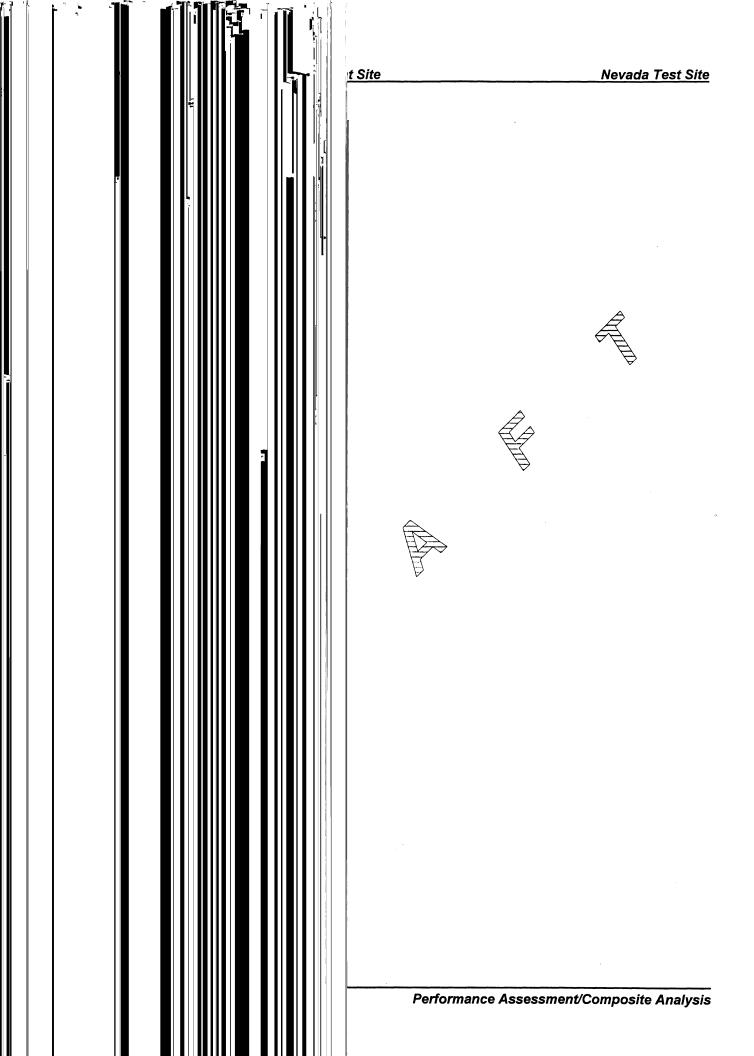
10-Year (in.)	25-Year (in.)	50-Year (in.)	100-Year (in.)
0.20	0.22	0.28	0.32
0.40	0.43	0.54	0.63
0.70	0.75	0.95	1.10
0.82	0.91	1.08	1.25
0.91	1.04	1.19	1.36
1.10	1.30	1.40	1.60
1.40	1.65	1.80	2.10
1.80	2.00	2.40	2.60

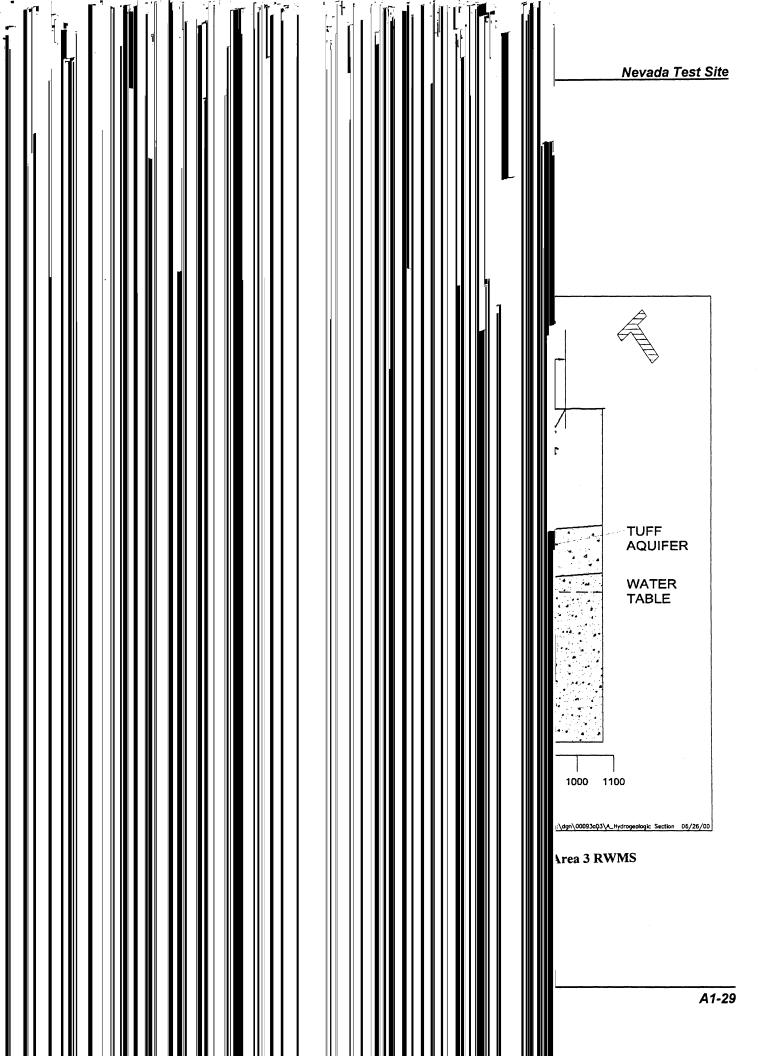






I.95€∓06	1.91e+06	1.91e+06	1.91e+06	1.99e+06	2.15e+06	3.99e+06	3.59e+06	2.55e+07	2.55e+07	2.55e+07	2.55e+07	2.80e+05	2.80e+05	2.80e+05	2.80e+05	2.80e+05	2.80e+05
Z.08e+03	2.01e+03	2.01e+03	2.01e+03	2.10e+03	2.27e+03	4.20e+03	3.78e+03	2.68e+04	2.68e+04	2.68e+04	2.68e+04	2.95e+02	2.95e+02	2.95e+02	2.95e+02	2.95e+02	2.95e+02
2.45 <b>E</b> -UI	2.40e-01	2.40e-01	2.40e-01	2.50e-01	2.70e-01	5.00e-01	4.50e-01	3.20e+00	3.20e+00	3.20e+00	3.20e+00	3.50e-02	3.50e-02	3.50e-02	3.50e-02	3.50e-02	3.50e-02
we	Eu <sup>152</sup>	Eu <sup>154</sup>	Gd <sup>152</sup>	H0 <sup>166</sup>	Pb <sup>210</sup>	Ra <sup>226</sup>	Ac <sup>227</sup>	Th <sup>229</sup>	230	Th <sup>232</sup>	231	32	ñ	4	32	36	38
2	<u>ш</u>	回	<u> </u>	Ħ —	 	Ra	- Ac	=	71730	÷ F	Pa <sup>231</sup>	$\left  U^{232} \right $	$\left  U^{233} \right $	$\left  U^{234} \right $	$0^{235}$	$\left  U^{236} \right $	U <sup>238</sup>
- 1.20e+v3	4.10e+04 E	1.47e+04 E	1.21e+05 G	4.10e+04 He	4 9e+05		3.19e+06 Ac	1.21e+05 Th	4.76e+06	1.28e+06 Th	1.28e+06 Pa	2.00e+03 $U^{2}$	4.40e+05 U <sup>23</sup>	$1.04e+06$ $U^{2}$	9.17e+03 U <sup>22</sup>	$2.23e+06$ $U^2$	2.23e+06 U <sup>2</sup>
		<del>-</del>								<del>&gt;</del>							
e+UV 1.25e+U3	e+01 4.10e+04	e+01 1.47e+04	e+02 1.21e+05	e+01 4.10e+04	4 9e+05	√ 3.19e+06	3.19e+06	e+02 1.21e+05	e+03 4.76e+06	e+03 1.28e+06	e+03 1.28e+06	e+00 2.00e+03	e+02 4.40e+05	e+03 1.04e+06	e+00 9.17e+03	e+03 2.23e+06	2.23e+06

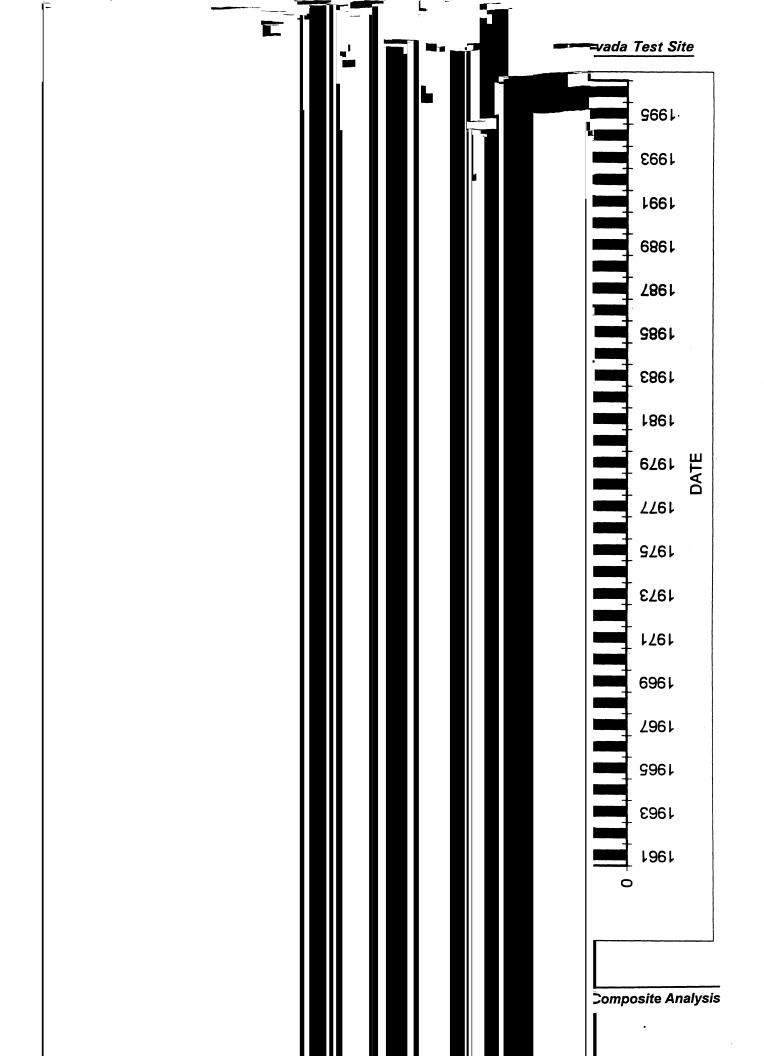




tracterization Boreholes at the Area 3 RWMS

Location Map

Nevada Test Site	RECIPITATION UN-ON	3 METERS PISODIC IFILTRATION VAPORATION DOT UPTAKE  5 METERS EARLY STEADY PWARD FLUX DME ROOT PTAKE	EARLY STEADY PWARD FLUX	bed Alluvium at the	A1-31
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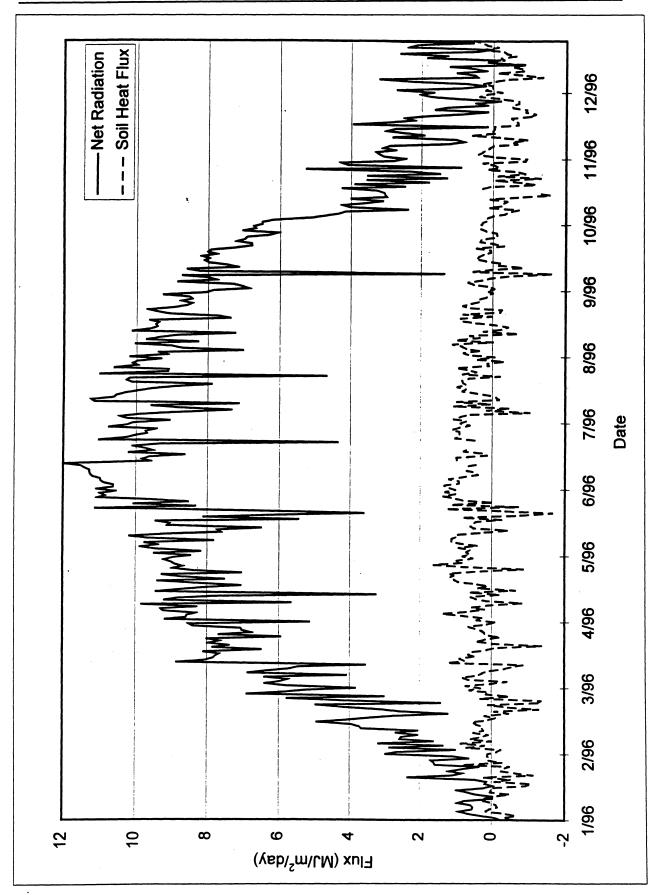


Figure A1.6 Mean Daily Net Radiation and Soil Heat Flux for 1996 at the Area 3 RWMS

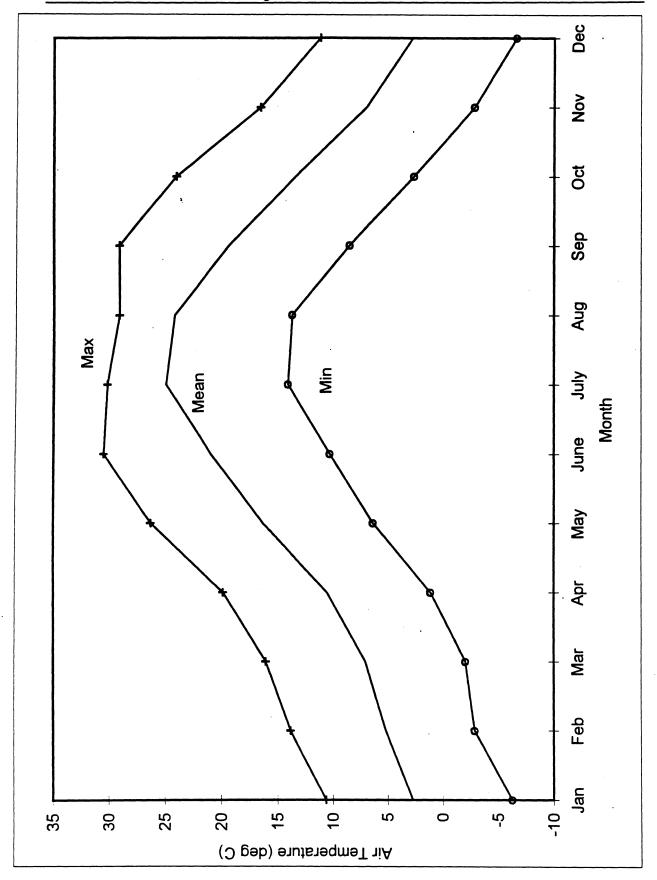


Figure A1.7 Monthly Maximum, Minimum, and Mean Air Temperatures at Yucca Flat for the Period 1962 to 1978

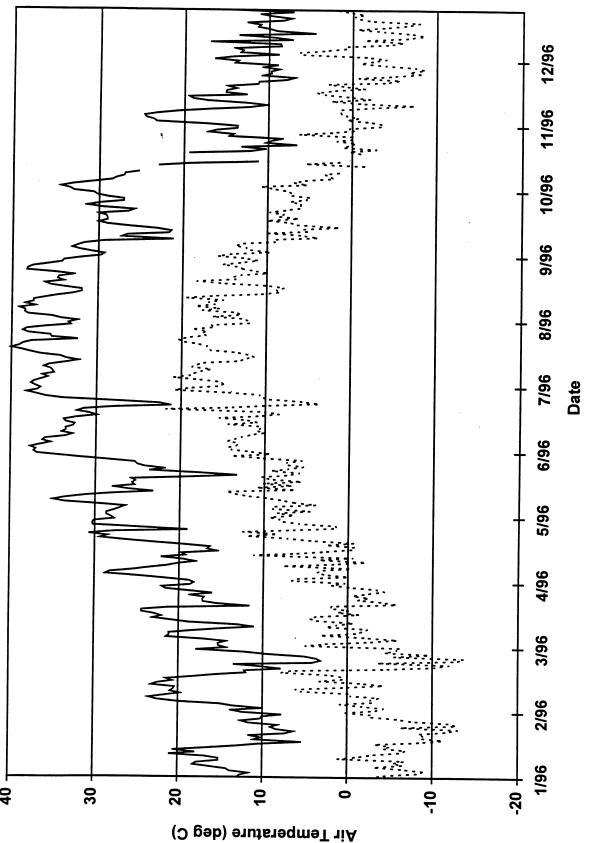


Figure A1.8 Daily Maximum and Minimum Air Temperatures for 1996 at the Area 3 RWMS

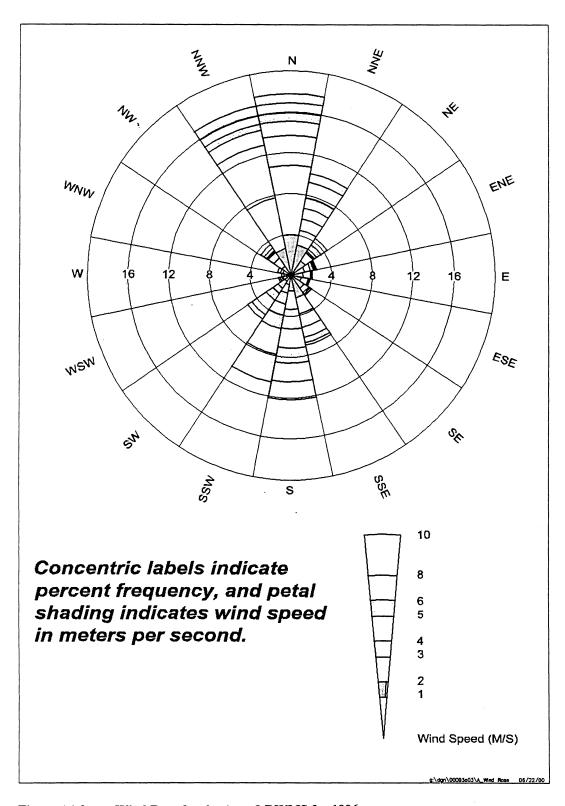
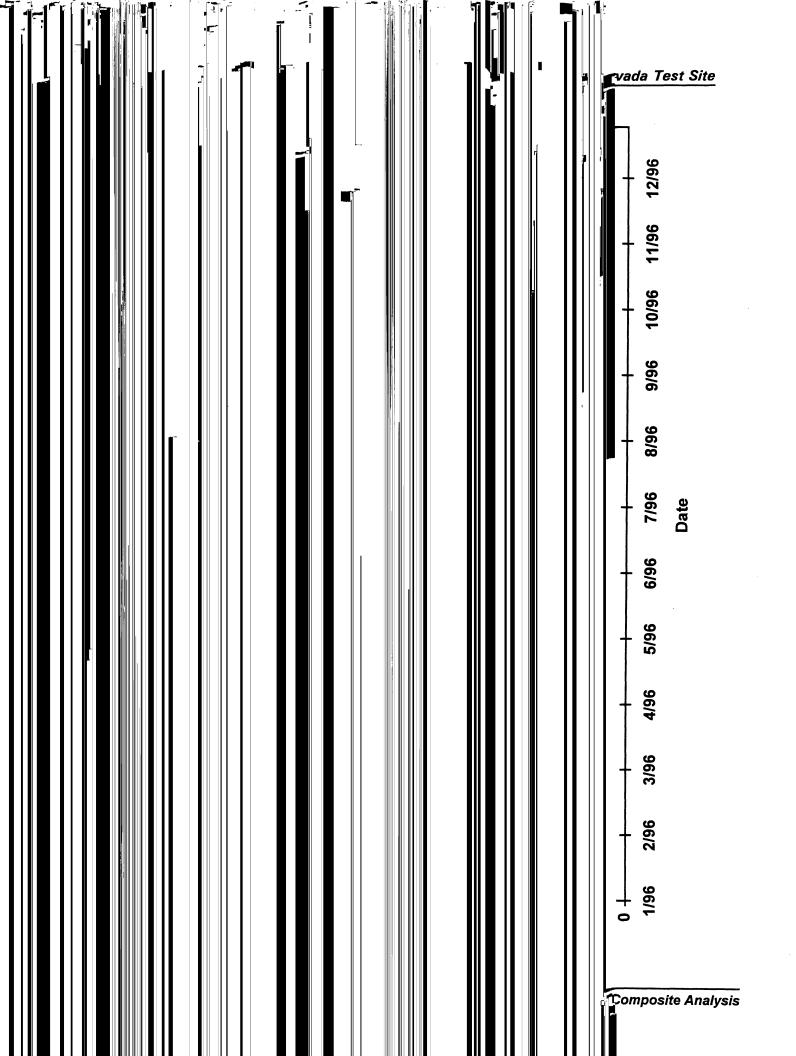


Figure A1.9 Wind Rose for the Area 3 RWMS for 1996



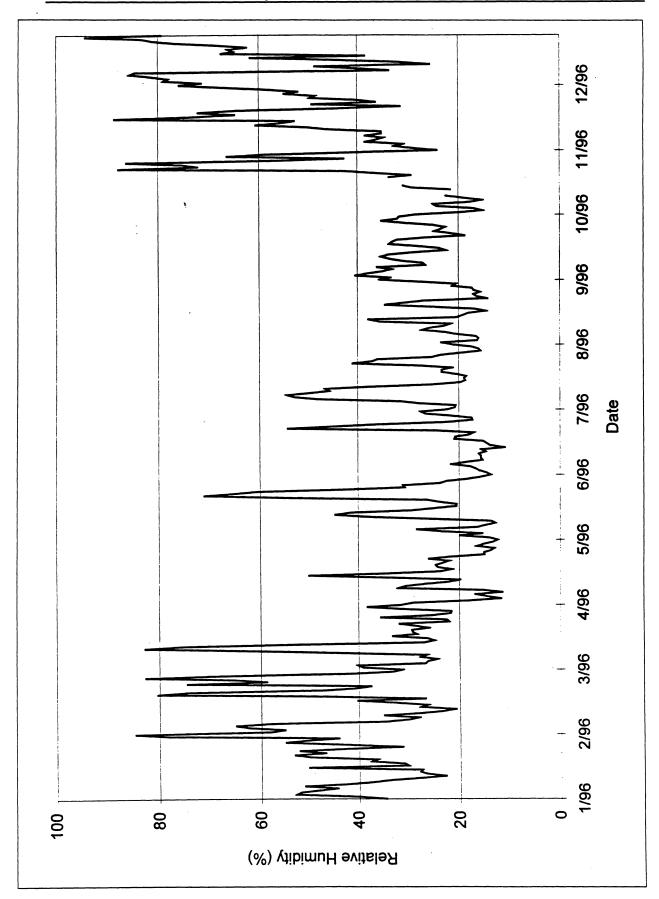


Figure A1.11 Mean Daily Relative Humidity for 1996 at the Area 3 RWMS

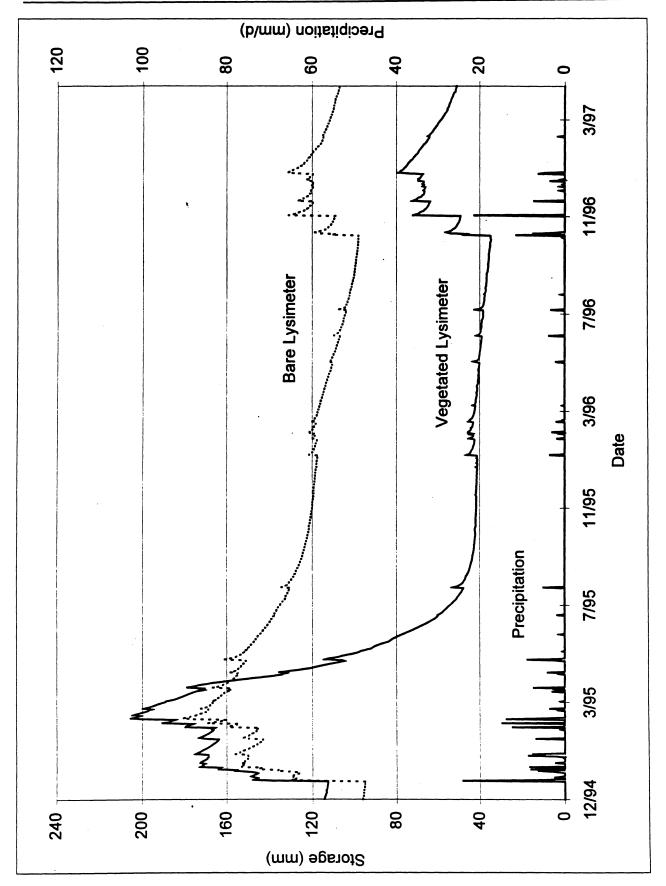


Figure A1.12 Frenchman Flat Lysimeter Water Storage and Precipitation for December 1994 Through April 1997

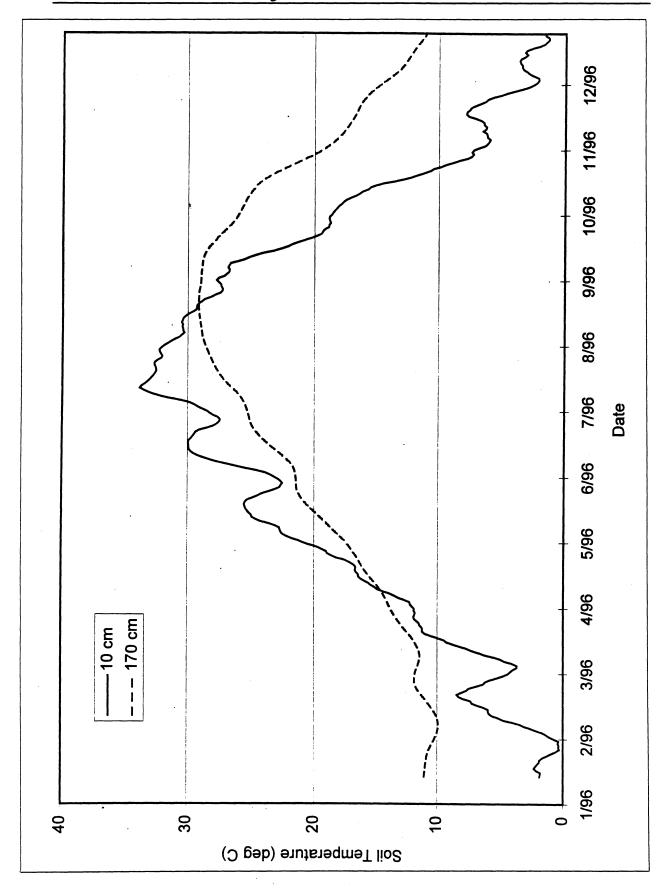


Figure A1.13 Soil Temperature Recorded at 0900 hr Daily at 10- and 170-cm Depths in the Vegetated Frenchman Flat Lysimeter

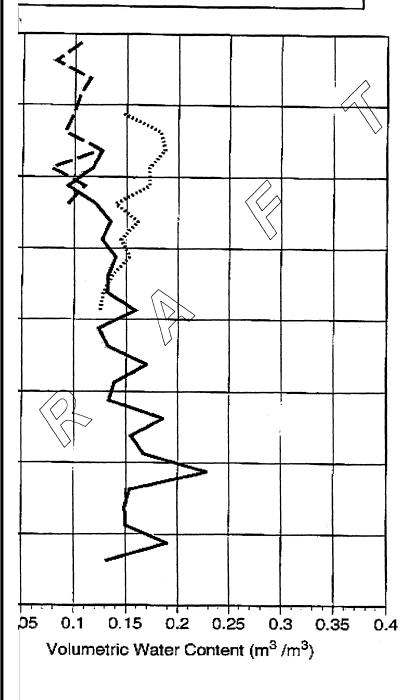
\CAOO\AREA\_3\PA\FINAL\A\_Precipitation 9/26/97

D Precipitation in the Vegetated Frenchman Flat

---- Undisturbed

U-3at/U-3bl Collapse Zones

..... U-3bh Collapse Zone



lumetric Water Contents with Depth for the Area 3 RWMS

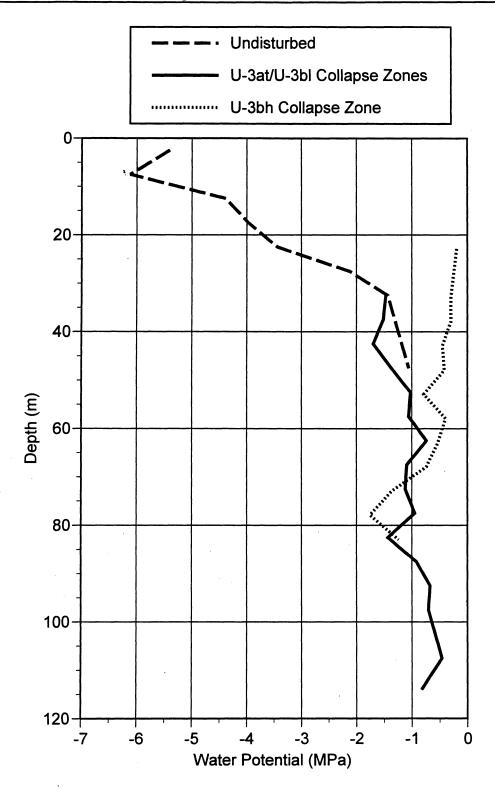
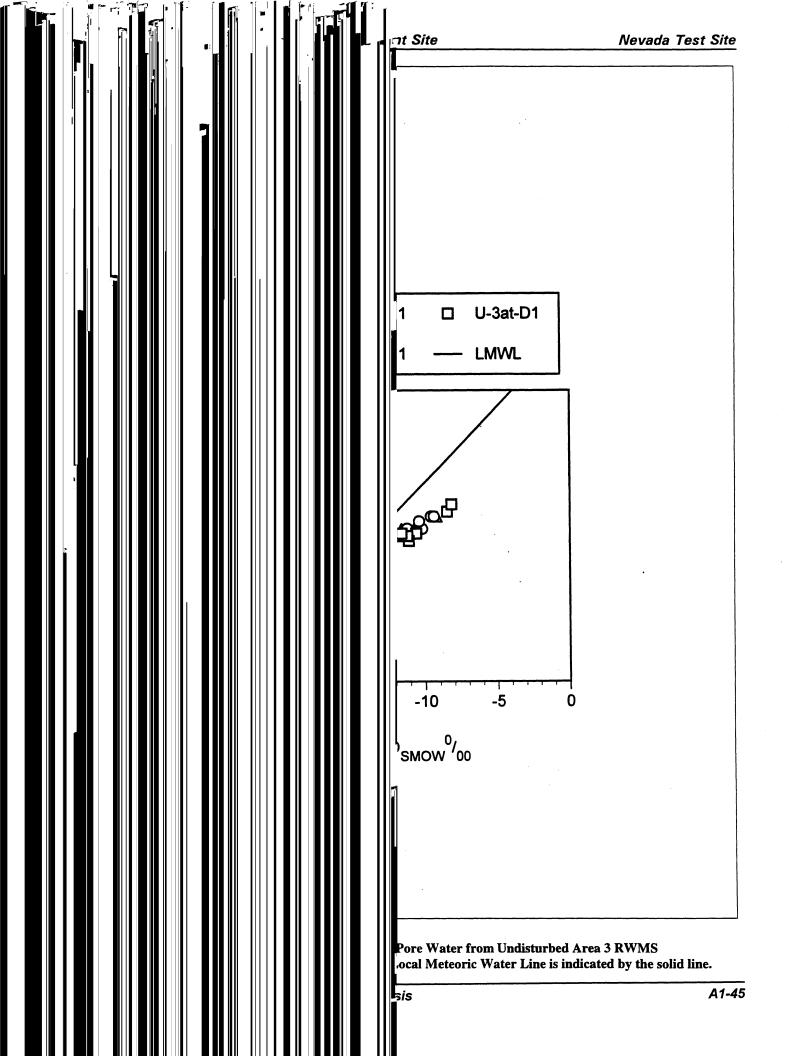
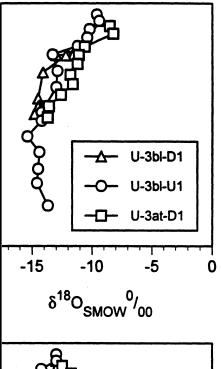
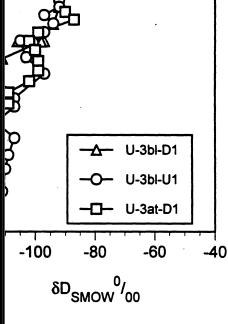


Figure A.1.16 Average Matric Potential with Depth for Area 3 RWMS.







ations in Pore Water with Depth for Undisturbed Area 3 RWMS

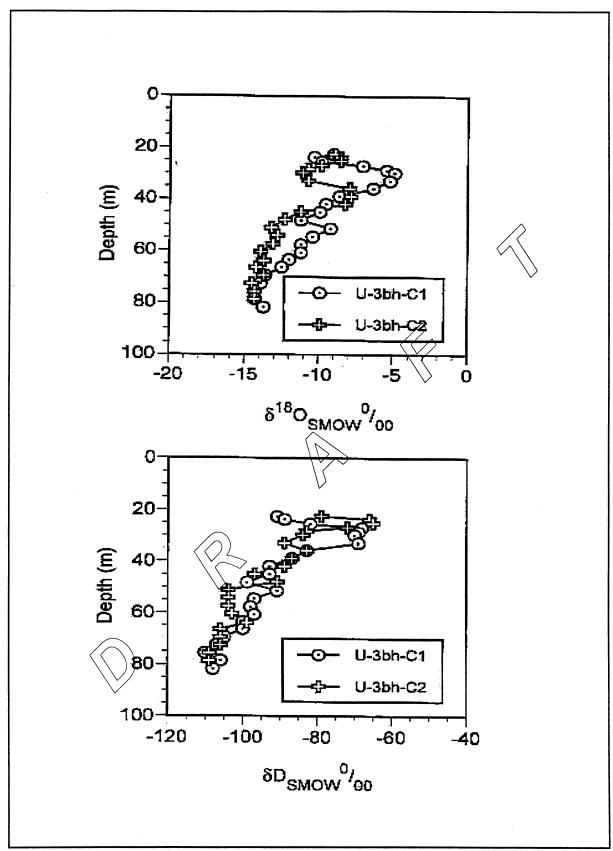
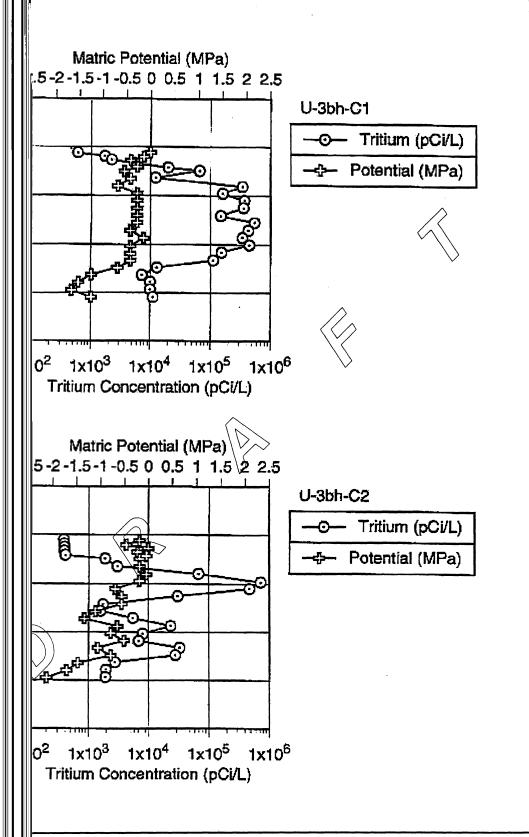


Figure A1.19 Stable Isotope Concentrations in Pore Water with Depth for Crater U-3bh Characterization Samples



ariation of Tritium Concentration and Matric Potential with Depth for haracterization Boreholes U-3bh-C1 and U-3bh-2

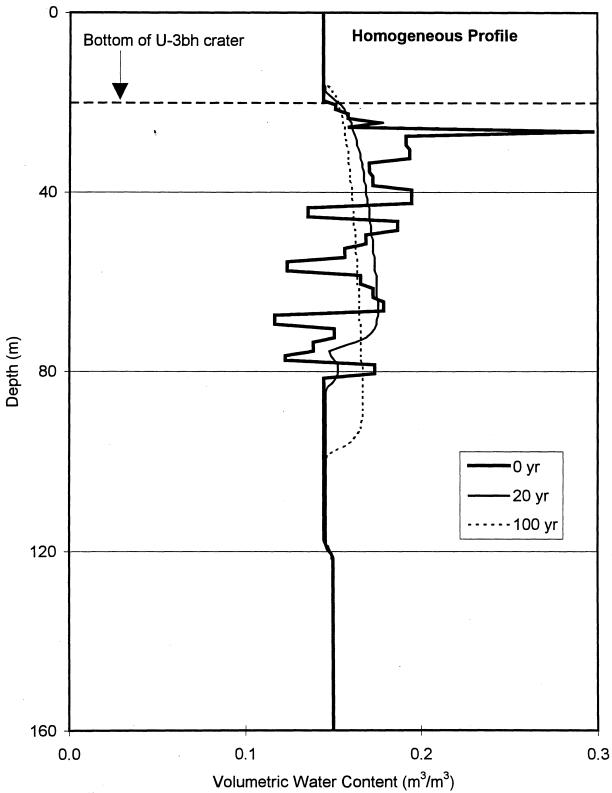


Figure A1.21 Simulated Water Content Profile in the U-3bh Collapse Zone Following Redistribution with a Homogeneous Profile

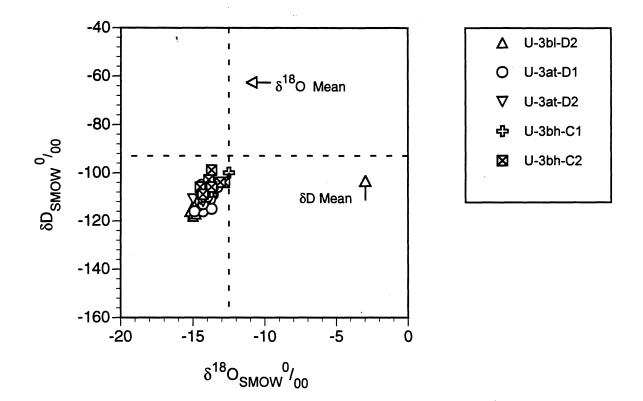


Figure A1.23 Stable Isotope Concentrations for Area 3 RWMS Characterization
Samples From Below 66 m Depth. The dashed lines indicate weighted mean concentrations for winter precipitation in Frenchman Flat

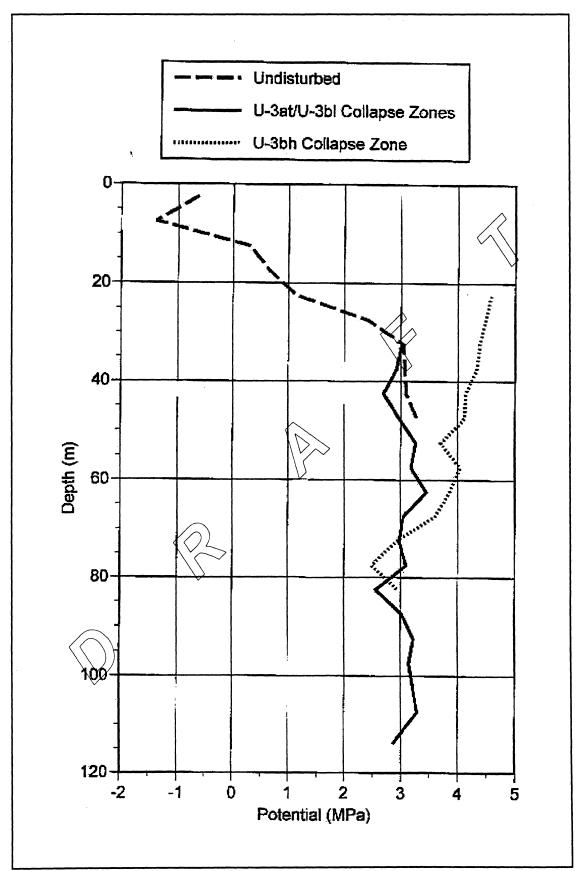


Figure A1.24 Average Total Potential with Depth for the Area 3 RWMS

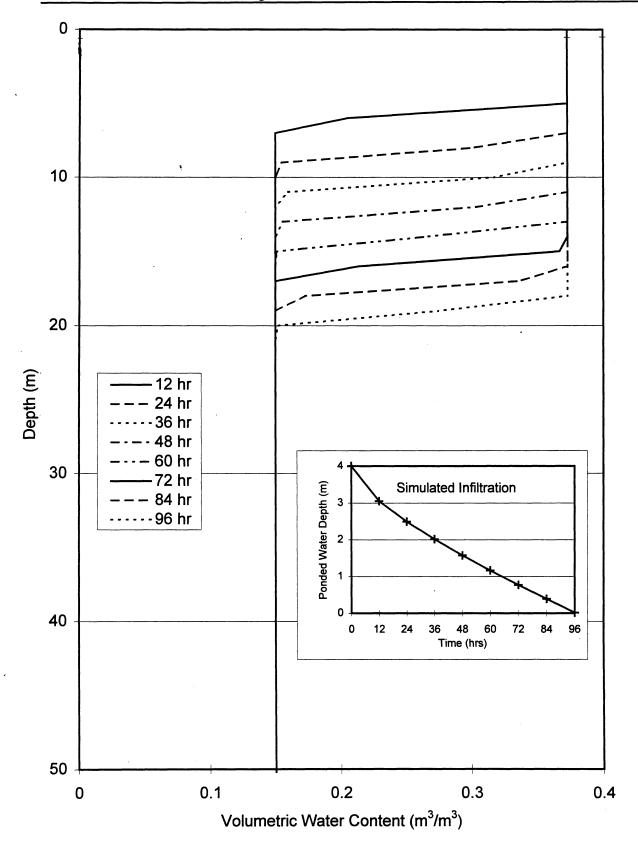


Figure A1.25 Simulation of Infiltration of 4 m of Flood Water Into Subsided U-3ah/at Waste Cell

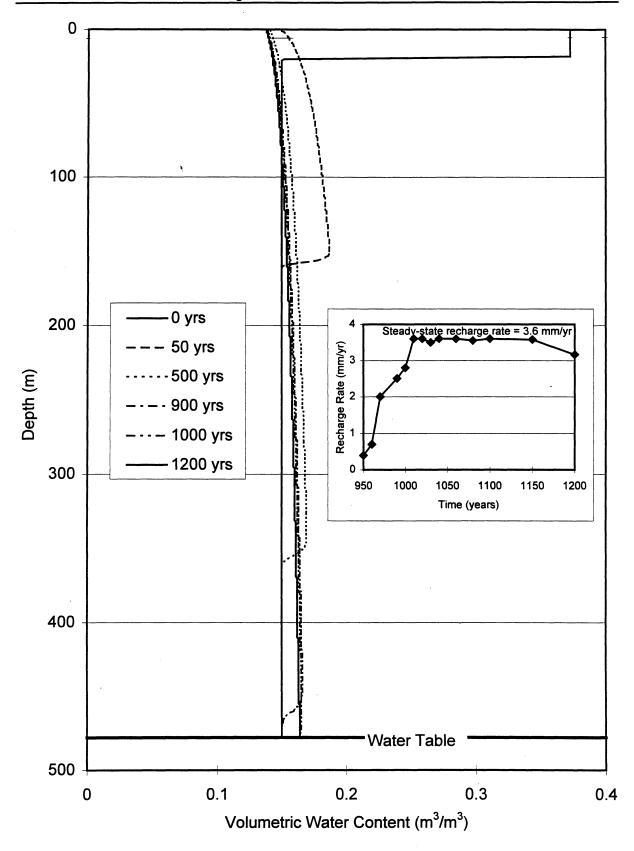


Figure A1.26 Simulation of Redistribution of 4 m of Flood Water Into Subsided U-3ah/at Waste Cell

# Appendix 2

**Estimation of Inventory at Facility Closure** 

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## <u>র Test Site</u>

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### Nevada Test Site

boundary. An the Area 3 RWMS have been joined to unit was used from e the U.S. 0.2A (DOE, 1988a), f the end of fiscal ion of this report, ng craters (U-3az,

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when the Waste solidation Project posal/storage sites and military red small volumes by 1 percent of the ource Conservation by 1 continued until a temporary cover sal unit.

er 8, 1989, U-3at ject. These wastes oximately between U-3at and er of 1989, most rators.

1995 was
U-3ah/at as of the

Composite Analysis

projects. Since that time, the U3-bh crater has received bulk te generators. As of the end of FY 1999, the U-3bh crater remained soil from environmental restoration cleanups.

#### sal Records

WMS. From the beginning of operations in July 1968 through ords were recorded on paper forms and log books. During this ompanying waste shipments were summarized annually on a ords the date of receipt, origin of the waste, identity of the waste, iners, total volume, total activity, burial site, and date of disposal.

disposal records were maintained in an electronic data base, fanagement Data Base (WMDB). Three of the four tables in the nipment number. Records in these tables, which include nuclide be retrieved on a shipment basis only. The WMDB tables are listed ing in FY 1993, waste disposals were recorded in a new data base, entory System (LWIS), which includes an additional table recording. The table recording the nuclide identity and activity is indexed by an shipment number. Therefore, LWIS activity and nuclide data tage basis. The LWIS tables are also listed in Attachment A.

ea 3 RWMS are heterogeneous in form. Prior to the al waste generator application process, waste form data were nents describing the processes generating the waste. In later years, itained waste source and form descriptions, that were limited to the types of materials that may be present. Waste streams different waste forms. Generators are currently required to provide the amount of any given waste form within a waste stream.

#### te Forms

t of the volume of waste disposed in U-3ax/bl was generated at the ved from atmospheric testing, underground nuclear testing, and a lide experiments conducted at the NTS. On an activity and volume testing operations is the predominant source of U-3ax/bl waste.

995) have previously summarized the waste forms in the U-3ax/bl ntainerized waste accounted for only 0.3 percent of the total it waste forms by volume were soil (51 percent), followed by int). The remainder of the waste forms were described as scrap action debris (2 percent), and equipment (0.1 percent).

### te Forms

al Management Project has contributed approximately approach of in U-3ah/at through FY 1995. These wastes are contained in steel inning in FY 1993, data base records began to include waste stream t can be matched with descriptions of waste streams in generator through FY 1995, 71 percent of the ONLO waste volume shipped as contaminated process area wastes ONLO-000000001). In lated process area wastes were described as contaminated scrap rocesses. The waste stream is currently material generated in the and waste stockpiled during previous operations. The waste wn proportions): plastic, cardboard and paper trash, incinerator lts, asphalt, floor sweepings, non-friable asbestos, refuse metal, wood, ceramics, glass, dust collector bags, furnace cleanings, scrap sonal protective equipment, compressed gas cylinders (valves aerosol cans.

vaste stream is the construction waste stream (ONLO-000000002), y 20 percent of the ONLO waste volume. The construction waste on debris from demolition, maintenance, or removal activities. s (in unknown proportions): soil, rock, gravel, concrete, metal, er trash, asphalt, glass, floor tile, roofing material, and other non-ing materials.

NLO waste can be estimated for FY 1993 through FY 1995 from ne and net mass. The volume weighted mean for the two waste The range for both waste streams was from 0.20 to 0.38 g cm<sup>-3</sup>. treams have densities ranging from 0.2 (cardboard) to 7.8 (steel) rials (asbestos, asphalt, concrete, glass, ceramics, rock, and soil) of 1 to 3 g cm<sup>-3</sup>. This is still substantially greater than the uggesting that there is a significant potential for compaction of

vaste generated from the clean-up nt to the NTS. These wastes are pactible trash such as contami-3bh will contain mostly soil from m off-site generators have also by of soil and construction debris.

### Disposal Unit

are found in two sources.

typewritten logs. Beginning in base (the WMDB) Some data
MDB. These records were

ften designated as gross activity y is often mixed fission products ty was assigned to mixed fission uivalent to gross activity derived that gross activity can have

1<sup>3</sup> of waste, containing 2.6 × / 1968 to August 1978 ximately 97 percent of the waste percent of the activity and th fission products, activation veapons testing. The single most f the volume and 91 percent of the for by wastes generated at the

assigned to five source terms with 2 weapons tests, Nuclear Rocket LO uranium. Activity designated was assigned an appropriate

7 1977 and continue until the site dicate that  $2.2 \times 10^5$  m<sup>3</sup> of waste unts for 96 percent of the total nerator of the waste, accounting

ss than 1 percent of the volume VI, AMDM, BCLA, BGAT, if the volume.

The major radionuclide on an The remainder of the activity is MFP (0.8 percent), and 20 other the activity.

### for U-3ax/bl

not support a long-lived parent decay to negligible levels during radionuclides that decay to long-plying by the ratio of the decay e progeny activity at the end of reported as mixtures or suspected iventory.

### nuclide Activity

ed as gross activity. The se inferred from the source of the throughout its operation from 34 ed on the NTS. In addition to gross ixture of fission products, activavities designated as MFP were ource.

s are not known in most cases. In coduct of a scaling factor and some cases, gross activity in fission secific gamma constant and the arious specific gamma constants n exposure rate measurements.

calculate the specific gamma

been partitioned among specific on for each source. The activity of as:

(A2.1)

where

q<sub>j</sub> = estimated activity of radionuclide j, Ci; q = gross activity (or MFP) reported by generators, Ci; f<sub>s,j</sub> = activity fraction of radionuclide j in source s, dimensionless; and activity fraction of reference nuclide (or nuclides) in source s, dimensionless.

In Equation A2.1, the activity of individual radionuclides is calculated as a fixed fraction of the gross activity reported by the generator. The fixed fraction is the ratio of the activity fraction of the radionuclide being estimated to the reference radionuclide. The reference radionuclide is the radionuclide that the generator assumed was present when estimating the gross activity. Selection of an appropriate fraction requires an assumption about the radionuclide composition of the source and an assumption that the reference radionuclide (or nuclides) are the same as nuclides contributing to the activity q. For a mixed fission product waste stream, the reference radionuclide (or nuclides) would typically be the radionuclides contributing to the measured gamma exposure.

### A2.4.3.2 Gross Activity Derived from Weapons Testing

Waste from 29 of the 34 sources of gross activity received at U-3ax/bl are known, suspected, or assumed to be contaminated with mixed fission products from weapons testing (Table A2.3). Combined, these generators contributed  $3.0 \times 10^2$  Ci of gross activity to U-3ax/bl, or approximately 98 percent of the total gross activity.

Ten sources (LFDD, LCAA, LCAB, LDNA, LLDN, LRY5, LRY10, LRY12, LRY13, and LRY14) were involved with underground nuclear testing occurring simultaneously with disposal at U-3ax/bl. Therefore, these generators are known to have generated wastes with fission products a few weeks to months old at the time of assay. Some of the inventory attributed to LCAB may be mixed fission and activation products that originated at the NRDS. Nevertheless, these wastes are assumed to contain a fission and activation products characteristic of underground nuclear testing. Six generators (ASLN, LEGL, LEPC, LRY3, LRY8, and LRY9) are suspected to have produced wastes containing fresh fission products. The generators designated ASLN, LEGL, and LEPC were all involved with nuclear testing, but have other possible radionuclide sources. No information could be developed for five generators (200R-LRY1, LRY15, LRY16, and CALA). Because waste streams derived from nuclear testing are the most common in terms of both activity and volume, it was assumed that any waste originating at the Area 5 RWMS would have most likely contained fission and activation products. The specific source of the Argonne National Laboratory waste is unknown. However, Argonne National Laboratory has had significant involvement with the development of reactor technologies and it was assumed that these wastes were derived from a fission source. The other three generators (200R, LRY15, LRY16) were quantitatively insignificant. They were assumed to contain MFP because no other information was available.

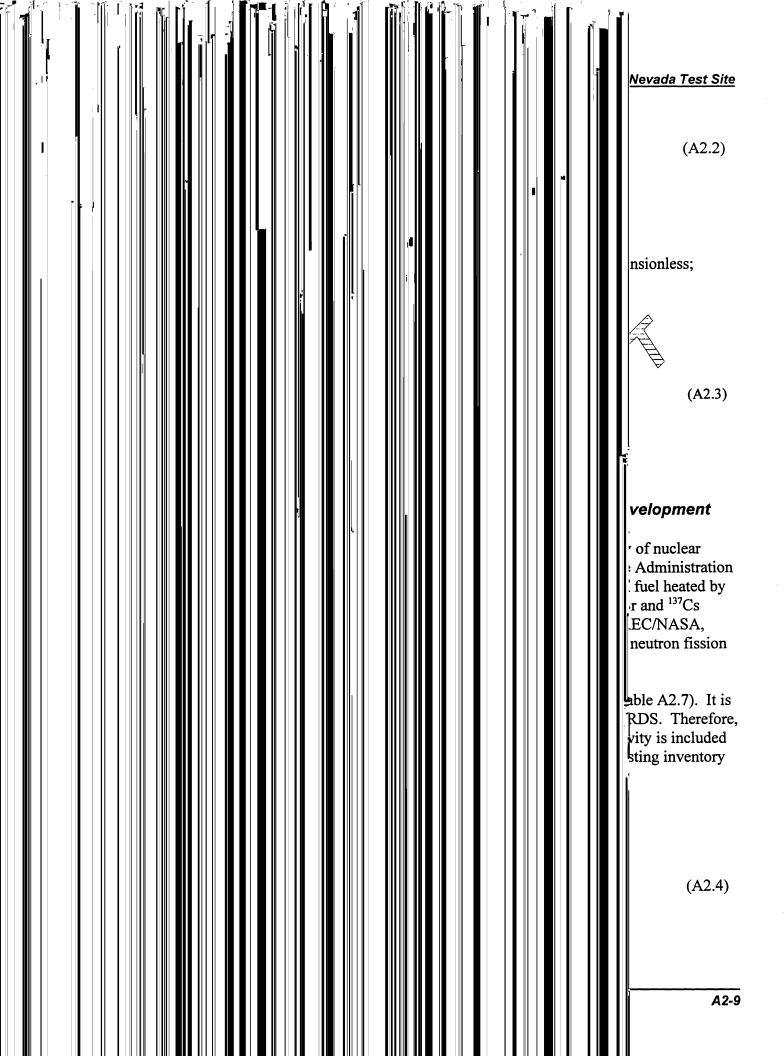
B, and LR7Y) are known to tor code LRY2 is suspected e Consolidation Project was and dispose of radioactive REECo, 1980, 1981, 1982, agle, 1988). Most of the ataminated by atmospheric ing debris from undermost underground events on products from the Waste assay and disposal began.

vas portioned among mposition of the gross ed radionuclide composition. The inventory of longons tests has been estimated to be representative of Mesa inventory was lide composition of the of all testing sources on e excluded waste codes aventory. The activity of assuming that 137Cs was the

### h Transuranic

e generated waste
. The Tweezer project was
e Area 5 TRU Storage Pad
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Pad is assumed to be
repackaging, and
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term fate and behavior
with weapons-grade Pu.

Ims described above was f Pu isotopes and <sup>241</sup>Am was calculated using
The activity fractions were The activity fraction for Pu



the generator, Ci; sss; ess;

135U (Walker et al., , 60Co, and 239Pu. For s estimated assuming 60Co, and 339Pu to ough other activation de given the small

nining mixtures of its often include the iree naturally may be significantly iring waste streams

generator and fiscal ition based on ng radionuclides

(A2.5)

ope, yr<sup>-1</sup>; , dimensionless;

nt/Composite Analysis

bay constant of the reference isotope, yr<sup>-1</sup>; fraction of the reference isotope, dimensionless; and f the unreported isotope, g mole<sup>-1</sup>.

e or two isotopes of uranium in uranium-bearing waste 2.8). Uranium-235 was the only nuclide reported by two ttachment B for waste generator codes). Based on nipments were corrected assuming a 93 percent enriched CAA shipments were corrected with the same small activity involved and conservativeness of the vas assumed to be 235U. Three generators shipped waste. These shipments were assumed to be depleted d as the reference. A third source, ONLO, was assumed The ONLO waste stream was corrected using the 238U an isotopic ratio reported by the generator for

DE facilities may be recycled from irradiated fuel (Rich nium may be contaminated with fission and activation h are <sup>99</sup>Tc, <sup>239</sup>Pu and <sup>237</sup>Np (Rich *et al.*, 1988). The only d enriched uranium in significant quantities is ONLO. led to contain a constant fraction of <sup>99</sup>Tc and <sup>237</sup>Np. because this is minor source of this radionuclide. generator D. Rast, personal communication), the × 10<sup>-4</sup> and the <sup>237</sup>Np/<sup>238</sup>U ratio was assumed to be 1.7 × vaste. These ratios represent the mean for wastes 295.

d using Equation A2.1, where the gross activity was the fraction for the reference radionuclide was set equal to <sup>9</sup>Pu and <sup>240</sup>Pu. Activity fractions were as in *Table A2.5*.

### he U-3ax/bl Disposal Unit

as obtained by summing all the revisions for gross es (Table A2.9). The total long-lived activity estimated  $)^3$  Ci. The total activity reported in waste management roximately equivalent to the  $1.2 \times 10^3$  Ci estimated by source of the small discrepancy in activity between e waste management records used in this report is view of the data base during FY 1996 may have caused v, in part, explain the discrepancy. The difference v revised inventory is largely attributable to the consure radionuclides with weak radiations such as v H. It

Analysis A2-11

# est Site of the 37Cs ately iese I 0<sup>5</sup> m<sup>3</sup>. 96. the A soil or Uvas has rring o-otivity. oxiunit and ission esting. peraity as vastes and nt), posed

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i of gross I (LDN1, waste of <sup>137</sup>Cs. 'not on ition of the lual prrection

m ion based

ler natural or 5 percent enriched waste streams can contain depleted, orted <sup>235</sup>U activities were assumed to ium waste stream. The reported <sup>238</sup>U ie stream. All shipments from

The isotopic composition was nelude a combination of various 1992 was assumed to be repretopic mixture. Waste streams im based on the generator's depleted uranium.

stant fraction of <sup>99</sup>T cand <sup>237</sup>Np. unication), the <sup>99</sup>Tc/<sup>238</sup>U ratio was sumed to be 1.7 × 10<sup>-5</sup> for all e mean for wastes shipped from

ste with <sup>239</sup>Pu as the only reported Pu .065 Ci of <sup>239</sup>Pu. The reported ty of <sup>239</sup>Pu and <sup>240</sup>Pu. The shipments opic composition in *Table A2.5*. The activity of <sup>239</sup>Pu was left

h/at Disposal Unit

ated as the sum of the data base ns increase the inventory of sed through FY 1995 increases from nuclides by activity at the date of cent), and uranium isotopes

## Disposal Unit

LWIS. These records indicate that 7,140 m³ of waste containing rastes were predominately soil from activity basis predominately of <sup>239</sup>Pu, les are assumed to be completely n place during disposal of this waste.

nated at future times using the Croff, 1983). The disposal units

Ince Assessment/Composite Analysis

volume to support operations through hat these disposal units will be full and only future disposals and radioactive isms were considered.

d with a temporary closure cap in ecaying the inventory estimated at closure ecays rapidly initially as <sup>3</sup>H and short-lived nundred years, the activity concentration ninated by long-lived isotopes of uranium times are provided in Attackment D.

it was open and receiving waste. The osal rate for each year in its operational as the mean rate observed from FY 1988 a, U-3ah/at has received 9.5 × 10<sup>4</sup> m<sup>3</sup> of 3ah/at was estimated from the September a nominal disposal rate of 2.6 ×

RWMS is also expected to receive BLE TRACKS site. The inventory of the ous site characterization data to be 3.6 Ci S waste was assumed to have the isotopic

l assuming 23 years of disposal operations. <sup>241</sup>Am were assumed to have a constant e from FY 1988 through FY 1995 d to be disposed at the nominal rate in all aCKS waste was assumed to be disposed. 5 was assumed to be the sum of the ory.

IGEN2 assuming only radioactive decay asis, the inventory of U-3ah/at is domisure is presented in *Table A2.14*. The present in Attachment E.

mated for U-3ah/at on a closure date of inant long-lived radionuclides on an 5 percent), <sup>90</sup>Sr (4 percent), <sup>234</sup>U of waste estimated to be disposed in

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<sup>7</sup>Cs n<sup>3</sup>. ated

of

## Sensitivity

inty is difficult as few data are available. Generators provide an tivity and volume with no accompanying statement of be used to estimate uncertainty, such as a description of the d and its assumptions or a description of the process generating illable. Generators often state that they prepare very conservatory. This is probably correct for radionuclides that are routinely in their facilities and processes, including nuclides such as <sup>3</sup>H, t are minor contaminants, difficult to measure, or insignificant to probably underestimated. This might include radionuclides U, and <sup>237</sup>Np.

## ates of Uncertainty

rces of uncertainty in the inventory estimated in this eport. ty in the estimated concentrations include:

s reported by the generator, is reported by the generator, teness of the records, of future waste, and of future waste.



inventory uncertainty are poor or nonexistent. Yet it is one of the most sensitive parameters affecting performance tainty has been addressed below by setting simple conservative adgment.

uncertainty in the activity and volume reported by generators. sed in the NTS waste acceptance criteria that acceptable waste undivided concentrations accurate to within an order of in (DOE/NV, 1992). Therefore, the true concentration of wastes assumed to be between 0.1 and 10 times the reported value. ed to compensate for some of the bias contributed by incomplete the activity of individual radionuclides estimated from gross sed on the physically reasonable range of errors expected for the tis made here to assess uncertainty in the future waste concensumed to have the same concentration and uncertainty as wastes

## ociated with Gross Activity and MFP Revisions

nt of the volume of waste sent to the U-3ax/bl disposal unit and to the U-3ah/at disposal unit was recorded as gross activity or identity or activity of any specific radionuclide. These gross

activities have been converted to radionuclide activities as described earlier. The uncertainty in these estimates can be bounded based on the physical reasonable limits of the waste characterization method.

Elletson and Johnejack (1995) reported that generators estimated gross radioactivity from exposure rate measurements. This is a common radioactive waste characterization method. Various conversion factors, or gamma constants, are reported to have been used by generators, ranging from 0.3 to 0.1 Ci hr<sup>-1</sup> R<sup>-1</sup> at 1 m (3 ft) (Elletson and Johnejack, 1995; Takahashi, personal communication, 1996). Conservatively, assuming a point source geometry, this implies a generator waste characterization model of

$$q = X\left(\frac{d^2}{\Gamma}\right) \tag{A2.6}$$

where

q = reported gross activity (or MFP activity) i; X = measured waste package exposure rate, R hr<sup>-1</sup>;

d = distance of package exposure rate measurement, m; and  $\Gamma$  = mixed fission product gamma constant, R m<sup>2</sup> hr<sup>-1</sup> Ci<sup>-1</sup>.

Combining Equation A2.6 with the equation used to estimate the revisions, Equation A2.1, the activity of individual radionuclides derived from gross activity was estimated as:

$$q_j = X \left( \frac{f_{s,j}}{f_{s,r}} \right)$$
 (A2.7)

A conservative range for  $q_j$  has been estimated through a Monte Carlo simulation of Equation A2.7

Exposure rates can typically be measured with an accuracy of  $\pm 20$  percent (National Council on Radiation Protection [NCRP], 1992). The mean exposure rate was assumed to be the reported gross activity times a gamma constant of 0.1 R m<sup>2</sup> hr<sup>-1</sup> Ci<sup>-1</sup>. The errors were assumed to be normally distributed around the mean with a 95 percent confidence interval being equal to the mean  $\pm 20$  percent. It is also assumed that technicians can reproduce the distance of the measurement to within 20 percent. The mean measurement distance was assumed to be 1 meter (m) (3 feet [ft]). Errors were assumed to be normally distributed about the mean with a 95 percent confidence interval being equal to the mean  $\pm 20$  percent. It was

#### Nevada Test Site

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distributed in a 55ft parallelepiped.
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me source was
Department of
× 7 ft steel box.
he gamma constant

iplex function of hanging radioed mixture of n fission of julation fission 992).

ixture with the age of the fission <sup>2</sup> Ci<sup>-1</sup> at 1 m (3 ft), nge of uncertainty lines. The 0.3 R hr<sup>-1</sup> t all times. Overall or of magnitude of n products evalutes relatively little for fresh fission m (3.3 ft). For at 1 m (3.3 ft).

estimated. Density
ma constant by a
crease the lower
instant causes a

at 1 m (3.3 ft) for fission m (3.3 ft) for older the limited data available.

nuclide composition was d for a simulated fission rvative throughout the time ue for the simulated fission ethod may overestimate mixtures less than one year cts because it assumes <sup>137</sup>Cs many short-lived radionucterization. These short-osure.

to be limited to uncertainty Variability caused by sed to the changing ucts, the activity fraction see Attachment C). For med to range from 0.01 to be uniform. The activity coefficients calculated oefficient was -0.96 for

sumed to be greater than the sy fractions are affected by duct activity fractions are ading the zero point. This is a limit of the activity

ntory was estimated by ted as a weighted mean of rvals for several fission and als are less than the plus or d inventories. Therefore, it ts characterized by direct Uncertainty in generator l value. This uncertainty

vity of individual or young fission products. uncertain, the revisions

essment/Composite Analysis

become more sensitive to waste geometry and density. Estimates of fission product activity in this Appendix become more conservative as the age of the fission products at the time of characterization decreases. The potential to underestimate activity exists for waste containing old fission products distributed through a large, dense waste form.

#### A2.8.3 Uncertainty in the Estimated U-3ax/bl Inventory

The U-3ax/bl inventory is dominated by activation products, fission products, and unfissioned weapon components from nuclear tests. The activity in NTS weapons testing-related waste streams is believed to have been estimated mostly from gamma exposure measurements. Uncertainties introduced from this method can be used to estimate the inventory uncertainty.

#### A2.8.3.1 Volatile Radionuclides

The volatile radionuclides <sup>3</sup>H, <sup>39</sup>Ar, and <sup>85</sup>Kr are assumed to be significantly overestimated. These nuclides were estimated assuming no losses by volatilization. Wastes are likely to lose some fraction of volatile radionuclides prior to disposal. This is suspected to be particularly true for the noble gases which may be overestimated by several orders of magnitude.

#### A2.8.3.2 Fission and Activation Products

A Monte Carlo analysis of the expected inventory for fission products characterized by gross radiation measurements was described above. The U-3ax/bl fission product inventory is about 10 percent old fission products derived from the Waste Consolidation Project and 90 percent fresh fission products. The estimated range of fission and activation product inventory for U-3ax/bl is described in *Table Azyro*. Fission and activation product range is assumed to be from 0.1 to 10 times the total inventory value.

#### A2.8.3.3 Actinides

Most actinides present in U-3ax/bl will be activation products or unfissioned weapon components from nuclear devices. Actinide activity from these sources was scaled from fission product activities and suffers from the same problems noted above for activation products. Wastes from the Waste Consolidation Project may be enriched in unfissioned actinides from low or negligible yield atmospheric tests. The same range of uncertainty was assumed for actinides as for activation products.

## A2.8.4 Uncertainty in the Estimated U-3ah/at Inventory

The U-3ah/at inventory can be divided into four general waste streams: (1) <sup>3</sup>H from off-site generators and weapons tests, (2) fission and activation products from the Waste Consolidation project, (3) uranium from Fernald, and (4) actinides from the cleanup of NTS Pu-contaminated soil.

#### A2.8.4.1 Volatile Radionuclides

The inventory of <sup>39</sup>Ar and <sup>85</sup>Kr is probably overestimated by many orders of magnitude because the primary source of these nuclides is old fission products from the Waste Consolidation Project. Tritium is probably overestimated in the U-3ah/at inventory as in the

be

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Table A2.1 Borehole, Test, Date, Depth, and Crater Volume for Subsidence Craters Developed Into the U-3ax/bl, U-3ah/at, and U-3bh Disposal Units

Crater	Test	Date	Test Depth (m)	Crater Volume (m³)
U-3ah	FISHER	12/03/1961	363	2.5 × 10 <sup>5</sup>
U-3ax	PACA	05/07/1962	258	$8.8 \times 10^4$
U-3bl	BOBAC	08/24/1962	195	$1.4 \times 10^{5}$
U-3at	JERBOA	03/01/1963	301	$2.5 \times 10^{5}$
U-3bh	HYRAX	09/14/1962	216	127 × 10 <sup>5</sup>

Table A2.2 Generator, Gross Activity, and Volume of Waste Disposed in U-3ax/bl From 1969 to 1978, as Recorded in Waste Management Log Books

6.3			Volume
Code	Generator Description	Activity (Ci)	(m³)
200R	200 Source Storage Building	$2 \times 10^{-4}$	2.8
ASLN	Sandia National Laboratories, NTS Operations	2 × 10 <sup>-4</sup>	0.11
LCAB	Los Alamos National Laboratory, NTS Operations	$2.3\times10^2$	$3.0 \times 10^{3}$
LEPC	Environmental Protection Agency, Las Vegas	0.010	2.0
LEGL	EG&G Atlas Facility, Las Vegas	$3 \times 10^{-5}$	0.08
LFDD	Sandia National Laboratories (FOD/DoD), Area 12 Tunnel Complex	13	$2.3 \times 10^{3}$
LCAA	Lawrence Livermore National Laboratory, Operations	0.053	73
LLDN	Defense Nuclear Agency, Area 12 Tunnel Complex	0.023	$4.7\times10^2$
LRY1	Reynolds Electrical & Engineering Co., Inc., Area 5 RWMS	0.010	14
LRY8	REECo, Area 23 Laboratory	0.0030	23
LRY10	REECo, Area 12 Tunnel Complex	10	$4.8\times10^2$
LRY12	REECo, Area 2 Drill Yard	$3 \times 10^{-4}$	1.8
LRY13	REECo, Area 6 Salvage Yard	0.016	$3.8 \times 10^{2}$
LRY14	REECo, Health Physics Department	0.14	$3.8 \times 10^{2}$
LRY15	No information available	0.051	57

Generator Description	Activity (Ci)	Volume (m³)
ea 18	1 × 10 <sup>-9</sup>	40
Area 11	$1.2 \times 10^{-4}$	0.14
rea 25	0.030	$1.7 \times 10^{2}$
ental Management Project	0.0060	$2.2 \times 10^{2}$
Total	$2.6 \times 10^2$	$7.6\times10^3$

rs Shipping Gross Activity to the U-3ax/bl Disposal Unit That Was erived from Atmospheric and Underground Nuclear Testing

nerator Description	Activity (Ci)	Volume (m³)
	2 × 10 <sup>-4</sup>	
uilding	⇒ 2 × 10 ·	2.8
ratories, NTS Operations	$2 \times 10^{-4}$	0.11
Laboratory, NTS Operations	$2.3 \times 10^{2}$	$3.4\times10^3$
tion Agency, Las Vegas	0.010	2.0
Las Vegas	$3 \times 10^{-5}$	0.08
ratories (FOD/DoD), Area 12 Tunnels	s 13	$2.3 \times 10^{3}$
Mational Laboratory, NTS Operations	12	$1.8\times10^3$
ney Area 12 Tunnel Complex	0.023	$4.7\times10^2$
IS. V	0.087	$2.0 \times 10^{4}$
oratory	0.071	$1.2 \times 10^{2}$
nel Complex	10	$4.8\times10^2$
Yard	$3 \times 10^{-4}$	1.8
ge Yard	0.016	$3.8 \times 10^{2}$
cs Department	0.14	$3.8 \times 10^{2}$
ıble	0.051	57
18	$1 \times 10^{-9}$	40
ncy, Area 12 Tunnel Complex	4.7	$1.4 \times 10^4$

Generator Description	Activity (Ci)	Volume (m³)
a 6 Decontamination Facility	0.011	$1.7 \times 10^{2}$
ste Consolidation Project, Site 1A	11	$5.8\times10^2$
ste Consolidation Project, Site 2A	$1.0 \times 10^{-9}$	19
ste Consolidation Project, Site 3C	$2.0 \times 10^{-9}$	$3.8\times10^2$
ste Consolidation Project, Site 3D	$1.0 \times 10^{-9}$	$3.6 \times 10^{2}$
ste Consolidation Project, Site 3E	1.0 × 10 <sup>-9</sup>	<b>54</b>
ste Consolidation Project, Site 4B	$9.0 \times 10^{-5}$	$ 8.0 \times 10^3 $
ste Consolidation Project (Site Unknown)	1.3	$3.0 \times 10^4$
a 3 RWMS, U-3ax/bl Disposal Unit	<u>~</u> 20	$1.7 \times 10^4$
a 3, U-3fi Borehole	0.018	$9.9 \times 10^{2}$
a 9 and Tunnels		23
tional Laboratory, East	0.012	27
ivity	$3.0 \times 10^{2}$	8.1 × 10 <sup>4</sup>

## ctivity Waste Sources Assumed to Be Contaminated with Transuranic iclides

Generator Description	Activity (Ci)	Volume (m³)
eezer Facility	1.2 × 10 <sup>-4</sup>	0.14
J Storage Pad	$2.8 \times 10^{-7}$	$1.2 \times 10^4$
lied Ecology Group, Area 23 Laboratory	0.055	$9.9 \times 10^{2}$
ivity	0.055	1.3 × 10 <sup>4</sup>

#### Nevada Test Site

Pu (from Shott et al., 1995)

## y Fraction at t = 20 yr

 $6.56 \times 10^{-3}$ 

0.262

0.0600

0.637

 $5.25 \times 10^{-6}$ 

0 022



vity Reported for Waste

## **Activity Fraction**

0.494

 $1.00 \times 10^{-5}$ 

 $6.87 \times 10^{-5}$ 

 $5.16 \times 10^{-8}$ 

 $1.34 \times 10^{-6}$ 

 $1.13 \times 10^{-7}$ 

 $6.77 \times 10^{-6}$ 

0.494

0.0111

Activity Generated at the

## Ci) Volume (m³)

 $6.2 \times 10^{3}$ 

 $2.4 \times 10^{2}$ 

 $6.3 \times 10^{5}$ 

sment/Composite Analysis

Recorded Inventory and Revisions for Uranium Isotopes Disposed in the U-3ax/bl Disposal Unit from FY 1977 Through FY 1988

Table A2.8

23sU 23sU 6.2×10 <sup>-5</sup>			HINGE	ndorost pa	Assumed Isotopic Mass Fractions	ctions	H	stimated K	Estimated Revisions (Ci)	
.2×10 <sup>-5</sup>			234U	Usez	U862	Ωœ	n <sub>ec</sub>	Ûse.	J. 138U	D <sub>967</sub>
< < <	93 6	93 % Enriched	0.0098	0.9315	0.055	0.004	0.0019		5.7×10 <sup>-7</sup>	8.0×10 <sup>-6</sup>
0.0026	93 (	93 % Enriched	0.0098	0.9315	0.055	0.004	0.17		5.2×10 <sup>-5</sup>	7.3×10 <sup>-4</sup>
7.2×10 <sup>-4</sup>	93 9	3 % Enriched	0.0098	0.9315	0.055	0.004	0.022	*	6.6×10 <sup>-6</sup>	9.3×10 <sup>-5</sup>
1.0×10-6	93 6	3 % Enriched	0.0098	0.9315	0.055	0.004	3.0×10 <sup>-5</sup>		9.2×10 <sup>-9</sup>	1.3×10 <sup>-7</sup>
0.001		epleted U	5×10-6	0.0025	0.9975		9.3×10 <sup>-5</sup>	1.6×10 <sup>-5</sup>		
0.01	~	epleted U	5×10-6	0.0025	0.9975		0.0012	2.0×10 <sup>-4</sup>		
5.2×1		(V) epleted U	5×10-6	0.0025	0.9975		4.9×10 <sup>-5</sup>	8.4×10-6		
4.0×1		epleted U	5×10-6	0.0025	0.9975		3.7×10 <sup>-5</sup>	6.4×10 <sup>-6</sup>		
0.00			44103	5×10 <sup>-6</sup>	0.9946		4.0×10 <sup>-4</sup>	2.1×10 <sup>-7</sup>		
0.036 0.54		1992 Ratio	4×10	5×10-6	0.9946		0.035	1.9×10 <sup>-5</sup>		
0.042 0.56	5						0.23	2.3×10 <sup>-4</sup>	5.9×10 <sup>-5</sup>	8.3×10 <sup>-4</sup>
0101		0.0010 0.012 5.2×10 <sup>4</sup> 4.0×10 <sup>4</sup> 0.006 0.54	0.0010 Depleted U 0.012 Depleted U 5.2×10 <sup>4</sup> Depleted U 4.0×10 <sup>4</sup> Depleted U 0.006 FY1992 Ratio 0.54 FY1992 Ratio 0.56	0.0010 Depleted U 0.012 Depleted U 5.2×10⁴ Depleted U 4.0×10⁴ Depleted U 0.006 FY1992 Ratio 0.54 FY1992 Ratio 0.56	0.0010 Depleted U 5×10° 0.012 Depleted U 5×10° 5.2×10⁴ Depleted U 5×10° 4.0×10⁴ Depleted U 5×10° 0.006 FY1992 Ratio 4×10° 0.54 FY1992 Ratio 4×10° 0.56	0.0010 Depleted U 5×10 <sup>-6</sup> 0.0025 0.012 Depleted U 5×10 <sup>-6</sup> 0.0025 5.2×10 <sup>-4</sup> Depleted U 5×10 <sup>-6</sup> 0.0025 4.0×10 <sup>-4</sup> Depleted U 5×10 <sup>-6</sup> 0.0025 0.006 FY1992 Ratio 4×10 <sup>-6</sup> 5×10 <sup>-6</sup> 0.54 FY1992 Ratio 4×10 <sup>-6</sup> 5×10 <sup>-6</sup>	0.0010 Depleted U 5×10 <sup>-6</sup> 0.0025 0.012 Depleted U 5×10 <sup>-6</sup> 0.0025 5.2×10 <sup>-4</sup> Depleted U 5×10 <sup>-6</sup> 0.0025 4.0×10 <sup>-4</sup> Depleted U 5×10 <sup>-6</sup> 0.0025 0.006 FY1992 Ratio 4×10 <sup>-6</sup> 5×10 <sup>-6</sup> 0.54 FY1992 Ratio 4×10 <sup>-6</sup> 5×10 <sup>-6</sup>	0.0010 Depleted U 5×10 <sup>-6</sup> 0.0025 0.9975 0.012 Depleted U 5×10 <sup>-6</sup> 0.0025 0.9975 5.2×10 <sup>-4</sup> Depleted U 5×10 <sup>-6</sup> 0.0025 0.9975 4.0×10 <sup>-4</sup> Depleted U 5×10 <sup>-6</sup> 0.0025 0.9975 0.006 FY1992 Ratio 4×10 <sup>-6</sup> 5×10 <sup>-6</sup> 0.9946 0.54 FY1992 Ratio 4×10 <sup>-6</sup> 5×10 <sup>-6</sup> 0.9946	0.0010         Depleted U         5×10°         0.0025         0.9975         9.3×10°           0.012         Depleted U         5×10°         0.0025         0.9975         0.0012           5.2×10⁴         Depleted U         5×10°         0.0025         0.9975         4.9×10°           4.0×10⁴         Depleted U         5×10°         0.0025         0.9975         3.7×10°           0.006         FY1992 Ratio         4×10°         5×10°         0.9946         4.0×10⁴           0.56         FY1992 Ratio         4×10°         5×10°         0.9946         0.035	0.0010         Depleted U         5×10-6         0.0025         0.9975         9.3×10-5         1.6×10-5           0.012         Depleted U         5×10-6         0.0025         0.9975         0.0012         2.0×10-4           5.2×10-4         Depleted U         5×10-6         0.0025         0.9975         4.9×10-5         8.4×10-6           4.0×10-4         Depleted U         5×10-6         0.0025         0.9975         3.7×10-5         6.4×10-6           0.006         FY1992 Ratio         4×10-5         5×10-6         0.9946         4.0×10-7         2.1×10-7           0.54         FY1992 Ratio         4×10-5         5×10-6         0.9946         0.035         1.9×10-5           0.56         FY1992 Ratio         4×10-7         5×10-6         0.9946         0.035         1.9×10-5





		3.5.		. 0/											
6.0 ×10 <sup>3</sup>	0.13	6.0 ×10-6	0.034	0.15	0.039	0.26	20	0.0064	0.77	19	$2.6 \times 10^{2}$	0.0091	0.97	0.029	
6,075							0.87				2.4	4.8 ×10 <sup>-5</sup>			
													\$		$\Diamond$
$5.4 \times 10^{2}$	$4.3 \times 10^{-3}$	6.9 ×10-8	$1.6 \times 10^{-3}$	0.014	$3.6 \times 10^{-3}$	0.013		$3.1 \times 10^{-4}$	0.033		<b>∂</b> 8	$8.0 \times 10^{-4}$	0.059	1.3 ×10 <sup>-3</sup>	
$4.3 \times 10^3$	0.12	5.8 ×10 <sup>-6</sup>	0.031	0.13	0.034	(1)		0.0059	0.71	17	$2.2 \times 10^2$	0.0080	0.88	0.027	
2.2	1,8 ×10 <sup>-5</sup>	2.8×10-10	6.8 ×10-6	5.9 ×10 <sup>-5</sup>	$1.5 \times 10^{-5}$	$5.2 \times 10^{-5}$		1.3 ×10 <sup>-6</sup>	1.3 ×10 <sup>-4</sup>	0.0078	960'0	3.3 ×10 <sup>-6</sup>	$2.4 \times 10^{-4}$	5.5 ×10 <sup>-6</sup>	
$1.4 \times 10^{2}$	0.0040	$1.9 \times 10^{-7}$	$1.0 \times 10^{-3}$	0.0045	0.0011	0.0079		2.0 ×10 <sup>-4</sup>	0.024	0.57	7.5	$2.7 \times 10^{-4}$	0.029	9.1 ×10 <sup>-4</sup>	
1.0×10³							19				0.22				
$H_{\epsilon}$	14C	26AI	12 <sub>96</sub>	$^{39}Ar$	$M_{0}$	41Ca	°,C0	iN <sub>6</sub>	iN <sup>69</sup>	85Kr	$^{1}$ S $^{00}$	$^{12}$ Cr	9N <sub>mE6</sub>	9N <sub>™</sub>	
	$1.0 \times 10^3$ $1.4 \times 10^2$ $2.2$ $4.3 \times 10^3$ $5.4 \times 10^2$ $0.075$	$1.0 \times 10^3$ $1.4 \times 10^2$ $2.2$ $4.3 \times 10^3$ $5.4 \times 10^2$ $0.075$ $0.0040$ $1.8 \times 10^{-5}$ $0.12$ $4.3 \times 10^{-3}$	$1.0 \times 10^{3}$ $1.4 \times 10^{2}$ $2.2$ $4.3 \times 10^{3}$ $5.4 \times 10^{2}$ $0.075$ $0.0040$ $1.8 \times 10^{-5}$ $0.12$ $4.3 \times 10^{-3}$ $1.9 \times 10^{-7}$ $1.9 \times 10^{-7}$ $5.8 \times 10^{-6}$ $6.9 \times 10^{-8}$	$1.0 \times 10^{3} \qquad 1.4 \times 10^{2} \qquad 2.2 \qquad 4.3 \times 10^{3} \qquad 5.4 \times 10^{2} \qquad 0.075$ $0.0040 \qquad 1.8 \times 10^{-5} \qquad 0.12 \qquad 4.3 \times 10^{-3}$ $1.9 \times 10^{-7} \qquad 2.8 \times 10^{-10} \qquad 5.8 \times 10^{-6} \qquad 6.9 \times 10^{-8}$ $1.0 \times 10^{-3} \qquad 6.8 \times 10^{-6} \qquad 0.031 \qquad 1.6 \times 10^{-3}$	$1.0 \times 10^3$ $1.4 \times 10^2$ $2.2$ $4.3 \times 10^3$ $5.4 \times 10^2$ $0.075$ $0.0040$ $1.8 \times 10^{-5}$ $0.12$ $4.3 \times 10^{-3}$ $0.075$ $1.9 \times 10^{-7}$ $1.9 \times 10^{-7}$ $5.8 \times 10^{-6}$ $6.9 \times 10^{-8}$ $1.0 \times 10^{-3}$ $0.031$ $1.6 \times 10^{-3}$ $1.6 \times 10^{-3}$ $0.0045$ $5.9 \times 10^{-5}$ $0.13$ $0.014$	$1.0 \times 10^3$ $1.4 \times 10^2$ $2.2$ $4.3 \times 10^3$ $5.4 \times 10^2$ $0.075$ $0.0040$ $1.8 \times 10^{-5}$ $0.12$ $4.3 \times 10^{-3}$ $0.075$ $1.9 \times 10^{-7}$ $1.8 \times 10^{-6}$ $5.8 \times 10^{-6}$ $6.9 \times 10^{-8}$ $1.0 \times 10^{-3}$ $0.031$ $1.6 \times 10^{-3}$ $0.014$ $0.0045$ $5.9 \times 10^{-5}$ $0.034$ $3.6 \times 10^{-3}$	$1.0 \times 10^3$ $1.4 \times 10^2$ $2.2$ $4.3 \times 10^3$ $5.4 \times 10^2$ $0.075$ $0.0040$ $1.8 \times 10^{-5}$ $0.12$ $4.3 \times 10^{-3}$ $0.075$ $1.9 \times 10^{-7}$ $1.8 \times 10^{-6}$ $5.8 \times 10^{-6}$ $6.9 \times 10^{-8}$ $6.9 \times 10^{-8}$ $1.0 \times 10^{-3}$ $0.0045$ $5.9 \times 10^{-3}$ $0.014$ $0.0044$ $0.0079$ $5.2 \times 10^{-3}$ $0.034$ $3.6 \times 10^{-3}$ $0.013$	$1.0 \times 10^{3} \qquad 1.4 \times 10^{2} \qquad 2.2 \qquad 4.3 \times 10^{3} \qquad 5.4 \times 10^{2} \qquad 0.0075$ $0.0040 \qquad 1.8 \times 10^{-5} \qquad 0.12 \qquad 4.3 \times 10^{-3} \qquad 0.0079$ $1.9 \times 10^{-7} \qquad 2.8 \times 10^{-6} \qquad 6.9 \times 10^{-8} \qquad 6.9 \times 10^{-8}$ $0.0045 \qquad 5.9 \times 10^{-5} \qquad 0.013 \qquad 0.014$ $0.0079 \qquad 5.2 \times 10^{-5} \qquad 0.034 \qquad 3.6 \times 10^{-3}$ $0.0013 \qquad 0.013 \qquad 0.013$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$						

1.9×10-6

 $2.2\times10^{-5}$ 

 $3.2\times10^2$ 

0.021 =

0.0086

9.6

 $3.5\times10^{-5}$ 

 $4.1\times10^{-4}$ 

0.0040

0.32

0.25 0.12

0.97

**58** 

 $2.8 \times \! 10^2$ 0900.0

0.12

9.3

0.45

137Cs ısıSm 150Eu

0.053 2.4

9:4 7.1

0.0068

 $3.3 \times 10^{-5}$  $5.4 \times 10^{-7}$ 

 $5.9 \times 10^{-4}$  $1.7 \times 10^{-5}$ 

2.4\\\10-6

 $1.7 \times 10^{-4}$ 

5.6 ×10<sup>-6</sup>  $2.0\times10^{-4}$ 

 $1.9 \times 10^{-4}$ 

	ŀ	

1.4 ×19<sup>-7</sup>

 $1.7 \times 10^{-6}$ 

 $6.0 \times 10^{-10}$ 

 $5.7\times10^{-8}$ 

6.7

4.9 ×10<sup>-4</sup>

0.22

154Eu 0H<sub>991</sub>

 $^{230}$ Th

152Eu

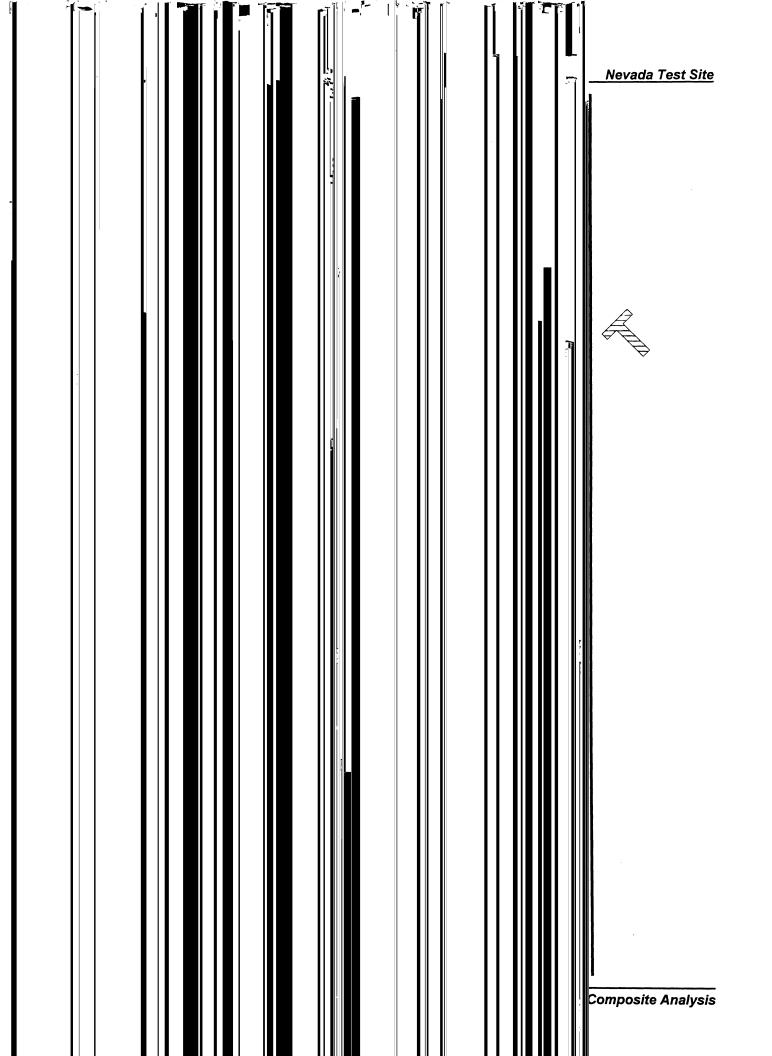
0.0010

0.30

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135Cs

 $I_{671}$ 



active Waste M	anagement Site	Nevada Test Site
(Undecayed Ci)	6.6 × 10³	
(Undecayed Ci)	5.7	
(Undecayed Ci)	0.40	
(Undecayed Ci) 0.023	6.0 ×10²	
(Undecayed Ci)	8.8 × 10³	
(Undecayed CJ) 9.4 ×10 <sup>-5</sup>		
(Undecayed CI)	1.6 × 10 <sup>2</sup>	
(Undecayed Ci) 9.4 3.1 × 10 <sup>2</sup>	1.3 ×10³	
24Cm MFP Gross Ci	Total	

A2-33

Assessment/Composite Analysis

Table A2.10 Generators Disposing Waste in the U-3ah/at Disposal Unit From FY 1988 Through FY 1995 and the Volume and Activity Contributed

Code	Generator	Percent of Total Activity	Percent of Total Volume
ALVI	Inhalation Toxicology Research Institute	< 1	< 1
AMDM	Mound Laboratories	25	< 1
ASLL	Sandia National Laboratories, Livermore, CA	< 1	< 1
BCLA	Lawrence Livermore National Laboratory, Livermore, CA	11	2
BGAT	General Atomics, San Diego, CA	<1	<1
BNRC	Rocketdyne, Canoga Park, CA	< 1	₩ <1
LCAA	Lawrence Livermore National Laboratory, NTS Operations	< 1	< 1
LCAB	Los Alamos National Laboratory, NTS Operations	√ < 1	< 1
LDN1	Defense Nuclear Agency, Area 12 Tunnel Complex	<1	< 1
LRY5	REECo, Area 6 Decontamination Facility	< 1	< 1
LRY7	REECo, Waste Management Consolidation Project	60	21
LRY8	REECo, Area 23 Laboratory	< 1	< 1
ONLO	Fernald Environmental Management Project	2	74
USAA	U.S. Army, Aberdeen Proving Ground, Aberdeen, MD	< 1	< 1





Recorded Inventory and Revisions for Uranium Isotopes Disposed in the U-3ah/at Disposal Unit From FY 1988 Through FY 1995

Table A2.11

Generatory Fiscal Year 234U BCLA/1989 BCLA/1990	U <sub>se</sub> f			CAOU		Assumed assumpte mass I havildus	2			×	A,
3CLA/1989 3CLA/1990		, 138U		0×2	Use	U867	7%I	n <sub>e</sub>	A <sub>SE</sub>	Λετ	D967
BCLA/1990		100	Natural	5×10 <sup>-5</sup>	0.0072	0.9927		0.014	6×10-4		
		0.022	Natural	5×10 <sup>-5</sup>	0.0072	0.9927		0.022	0.0010		
BCLA/1990	1.7×10 <sup>-5</sup>		5 % Enriched	3×10 <sup>-4</sup>	0.052	0.9473		0.012	ŧ.	5×10 <sup>-5</sup>	
BGAT/1988	7.2×10 <sup>-4</sup>		93 % Enriched	0.0098	0.9315	0.055	0.004	0.022		7×10-6	1×10-4
BGAT/1994	0.030		93 % Enriched	8600.0	0.9315	0.055	0.004	0.91		3×10 <sup>-4</sup>	0.0039
BGAT/1995	0.0054		93 % Enriched	0.0098	0.9315	0.055	0.004	0.16		5×10-5	7×10 <sup>-4</sup>
ONLO/1988	0.063	2.6	FY1992 Ratio	4×10-6	5×10-6	0.9946		1.5			
ONLO/1989	0.012	0.57	FY1992 Ratio	4×10-6	5×10-6	0.9946		0.33			
ONLO/1991	0.0027	0.082	FY1992 Ratio	4×10-6	\$ Olks	0.9946		0.048			
ONLO/1992 0.066	0900:0 99	0.18	FY1992 Ratio	4×10-6	9-00 X	0.9946		0.11			
ONLO/1992 0.18	8 0.0077	0.24	FY1992 Ratio	4×10-6	5×10-6	0.9946		0.14			
USAA/1992	-	3×10-6	Depleted	5×10-6	0.0025	0.9975		3×10 <sup>-7</sup>	5×10-8		
Total 0.24	4 0.13	3.7				1	4	3.2	0.0017	4×10-4	0.0046



 $1.2 \times 10^{-5}$ 

 $3.4\times10^{\text{-8}}$ 

 $1.4 \times 10^{-8}$ 

 $1.1 \times 10^{-9}$ 

 $1.2 \times 10^{-5}$ 

107Pd

Total Estimated (Undecayed Ci) Management records. Columns 3 through 7 represent revisions made as described in the text. Column 8 is the sum of Waste Management Inventory for FY 1988 to  $2.5\times10^{\text{-7}}$ FY 1995  $5.0 \times 10^{-5}$  $3.1 \times 10^{2}$  $2.5 \times 10^{-4}$  $3.4 \times 10^{-4}$ 0.0053 0.0014 0.0058 0.0015 0.0012 0.0058 0.010 0.038 0.031 0.80 9.7 Recorded Inventory and Revisions for the U-3ah/at Disposal Unit for FY 1988 Through FY 1995. Column 2 represents Waste (Undecayed Ci) **Uranium and** Plutonium 0.0033 records and revisions. Undecayed Curies indicates that activity is not decay from disposal to FY1995. (Undecayed Ci) **Gross Activity** A-12 Tunnel  $1.8 \times 10^{-6}$ Complex  $9.3 \times 10^{-11}$  $1.9 \times 10^{-5}$  $7.9 \times 10^{-5}$  $2.2 \times 10^{-6}$  $4.9 \times 10^{-6}$  $5.7 \times 10^{-6}$  $1.7 \times 10^{-5}$  $4.1 \times 10^{-7}$  $4.4 \times 10^{-5}$  $1.1 \times 10^{-6}$ 7.6 × 10<sup>₹</sup> 0.0025 0.031 (Undecayed Ci) **Gross Activity** Yucca Flat  $2.8 \times 10^{-6}$  $2.9 \times 10^{-10}$  $6.6 \times 10^{-6}$  $1.7 \times 10^{-6}$  $8.4 \times 10^4$  $3.9 \times 10^{-7}$  $4.3 \times 10^{-5}$  $1.5 \times 10^{-6}$  $3.5 \times 10^{-5}$  $1.3 \times 10^{-6}$  $5.9 \times 10^{-6}$  $1.2 \times 10^{-5}$  $2.9 \times 10^{-7}$ 0.011 0.21 Tunnel Complex (Undecayed Ci) **MFP A-12**  $2.5 \times 10^{-7}$  $3.0 \times 10^{-12}$  $1.6 \times 10^{-7}$  $6.2 \times 10^{-7}$  $8.2 \times 10^{-5}$  $2.6 \times 10^{-6}$  $1.9 \times 10^{-7}$  $7.2 \times 10^{-8}$  $1.3 \times 10^{-8}$  $1.4 \times 10^{-6}$  $5.8 \times 10^{-8}$  $5.5 \times 10^{-7}$  $3.5 \times 10^{-8}$ 0.0010 0.024 MEP Yucca Flat (Undecayed Ci)  $2.5 \times 10^{-7}$  $.8 \times 10^2$  $3.4 \times 10^{-4}$ 0.0015  $2.5 \times 10^{-4}$ 0.0012 0.0014 0.0025 0.0051 0.0057 0.038 0.010 0.031 0.74 9.7 Data Base Totak (Undecayed Ci)  $1.2 \times 10^{2}$  $1.2 \times 10^{4}$  $5.0 \times 10^{-5}$  $5.0 \times 10^{-7}$ 0.0033 0.065 Radionuclide  $^{39}Ar$ 85Kr 93mNb Table A2.12 41Ca ပ္မွ iZ S 63Ni  $^{90}Sr$  $^{93}Zr$ %Nb 26Al S C ξ δĀ  $^{3}\!\mathrm{H}$ 

Table A2.12 (continued)

ea 3 Radioa	ictiv I	e W	<u>aste</u>	Mar	nage	<u>mer</u>	nt Si	te									Nev
Total Estimated Inventory for FY 1988 to FY 1995 (Undecayed Ci)	0.0086	0.026	$3.1 \times 10^{-4}$	$7.2 \times 10^{-6}$	$2.6 \times 10^{-4}$	12	0.41	$5.4 \times 10^{-4}$	0.38	0.29	$7.3 \times 10^{-8}$	0.14	$3.5 \times 10^{-5}$	0.0028	0.0022	0.14	
Uranium and Plutonium (Undecayed Ci)			ì,											,			
Gross Activity A-12 Tunnel Complex (Undecayed Ci)	$2.6 \times 10^{-5}$	$9.8 \times 10^{-5}$	$1.1 \times 10^{-6}$	$2.3 \times 10^{-8}$	$7.9 \times 10^{-7}$	0.038	0.0013	$1.1 \times 10^{-5}$	$3.4 \times 10^{-4}$	$1.6 \times 10^{-4}$	$1.9 \times 10^{-10}$		$\triangle$	$6.0 \times 10^{-10}$	$2.6 \times 10^{-6}$	1.8 × 10 <sup>-6</sup>	
Gross Activity Yucca Flat (Undecayed Ci)	7.5 × 10 <sup>-6</sup>	$3.0\times10^{-5}$	$3.6 \times 10^{-7}$	$8.2\times10^{-9}$	$3.0 \times 10^{-7}$	0.014	$4.7 \times 10^{-4}$	$6.1 \times 10^{-7}$		3.3 × 10 <sup>-4</sup>	$8.4 \times 10^{-11}$	<b>\(\left\)</b>		$2.7 \times 10^{-12}$	$2.5 \times 10^{-6}$	$1.0 \times 10^{-6}$	
MFP A-12 Tunnel Complex (Undecayed Ci)	$8.6 \times 10^{-7}$	$3.2 \times 10^{-6}$	$3.7 \times 10^{-8}$	7.5 × 10 <sup>-10</sup>	$2.6 \times 10^{-8}$	0.0012	$4.3 \times 10^{-5}$	$3.7 \times 10^{-7}$	1.1 × 10 <sup>-5</sup>	$5.2\times10^{-6}$	$6.3 \times 10^{-12}$			$2.0 \times 10^{-11}$	$8.6 \times 10^{-8}$	$5.8 \times 10^{-8}$	·
MFP Yucca Flat	9900:0	0.026	$3.1 \times 10^{-4}$	7.2 × 10 <sup>-6</sup>	2.6 × 10 <sup>-4</sup>	12	0.41	$5.3 \times 10^{-4}$	0.38	0.29	$7.3 \times 10^{-8}$			$2.4 \times 10^{-9}$	0.0022	$9.0 \times 10^{-4}$	
Data Base Total (Undecayed Ci)		-/				0.0041						0.14	$3.5 \times 10^{-5}$	0.0028		0.14	
Radionuclide	113mCd	121mSn	126Sn	$I_{621}$	132Cs	137Cs	mS <sub>181</sub>	₁₅₀Eu	152Eu	154Eu	0Н991	227Ac	<sup>230</sup> Th	222Th	$\Omega^{252}$ U	J <sup>233</sup> U	

Table A2.12 (continued)

Radionuclide	Data Base Total (Undecayed Ci)	MFP Yucca Flat (Undecayed Ci)	MFP A-12 Tunnel Complex (Undecayed Ci)	Gross Activity Yucca Flat (Undecayed Cl)	Gross Activity A-12 Tunnel Complex (Undecayed CI)	Uranium and Plutonium (Undecayed Ci)	Total Estimated Inventory for FY 1988 to FY 1995 (Undecayed Ci)
234U	0.55	$8.4 \times 10^{-4}$	$4.1 \times 10^{-8}$	$9.7 \times 10^{-7}$	1.3 × 10 <sup>-6</sup>	3.2	3.8
$\Omega_{SEZ}$	0.11	$2.3 \times 10^{-5}$	$5.6 \times 10^{-10}$	$2.6 \times 10^{-8}$	$1.7 \times 10^{-8}$	0.0017	0.12
$\Omega_{962}$		$2.0 \times 10^{-5}$	$1.6 \times 10^{-9}$	$2.3 \times 10^{-8}$	4.9 × 10-8	0.0046	0.0047
$\Omega_{862}$	4.1	$4.2 \times 10^{-5}$	$7.4 \times 10^{-10}$	$4.8 \times 10^{-8}$	$2.3 \times 10^{-8}$	$3.8 \times 10^{-4}$	4.1
dN <sup>752</sup>		$6.6 \times 10^{-5}$	$1.2 \times 10^{-8}$	$7.5 \times 10^{-8}$	$3.8 \times 10^{-7}$	$7.0 \times 10^{-5}$	$1.4 \times 10^{-4}$
238Pu	0.64	0.071	$2.4 \times 10^{-6}$	$8.1 \times 10^{-5}$	$7.4 \times 10^{-5}$	0.0013	0.71
<sup>239</sup> Pu	990.0	0.17	$6.5 \times 10^{-6}$	$2.0 \times 10^{-4}$	$2.0 \times 10^{-4}$		0.24
$^{240}$ Pu	$3.3 \times 10^{-4}$	0.044	$2.1\times10^{-6}$	$5.1 \times 10^{-5}$	$6.4 \times 10^{-5}$	0.012	0.057
<sup>241</sup> Pu	0.041	0.62	$3.0 \times 10^{-5}$	$7.1 \times 10^{-4}$	$9.3 \times 10^{-4}$	0.13	0.79
<sup>242</sup> Pu	$6.4 \times 10^{-7}$	$2.7 \times 10^{-5}$	$1.1 \times 10^{-9}$	$3.1 \times 10^{-8}$	$3.5 \times 10^{-8}$	1.1 × 10 <sup>-6</sup>	$2.9 \times 10^{-5}$
241Am	$1.0 \times 10^{-4}$	0.041	$1.6 \times 10^{-6}$	$4.7 \times 10^{-5}$	$4.8 \times 10^{-5}$	0.0068	0.048
<sup>243</sup> Am	$2.0 \times 10^{-13}$	$2.0 \times 10^{-5}$	$6.0 \times 10^{-11}$	$2.3 \times 10^{-8}$	$1.8 \times 10^{-9}$		$2.0 \times 10^{-5}$
<sup>244</sup> Cm	0.0010	0.014	$1.0 \times 10^{-6}$	$1.6 \times 10^{-5}$	$3.1 \times 10^{-5}$		0.015
MFP	12						
Total	$1.4 \times 10^{2}$	$2.1 \times 10^{2}$	0.026	0.24	0.80	4.5	$3.4 \times 10^{2}$

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- .0-8
- $0^{-9}$
- 0-8
- 0-9
- 0-8
- 0-10
- 0-10
- 0<sup>-8</sup>
- 0-5
- $0^{-10}$
- 10-8
- l 0<sup>-9</sup>
- 10-8
- 0-11
- 10-8
- 10-8
- $0^{-10}$
- 0-11
- 0-10
- 10<sup>-5</sup>
- 10<sup>-7</sup>

imated ntory at ure (Ci)	Estimated Mean Activity Concentration at Closure (Ci m <sup>-3</sup> )
× 10 <sup>-4</sup>	1.2 × 10 <sup>-9</sup>
).092	$8.4 \times 10^{-7}$
).069	
× 10 <sup>-8</sup>	$1.7 \times 10^{-13}$
× 10 <sup>-4</sup>	$\sqrt{4.2} \times 10^{-9}$
.0012	$1.1 \times 10^{-8}$
.0030	$2.8 \times 10^{-8}$
× 10 <sup>-7</sup>	$2.1 \times 10^{-12}$
.0029	$2.6 \times 10^{-8}$
× 10 <sup>-6</sup>	$3.1 \times 10^{-11}$
× 10 <sup>-4</sup>	$3.5 \times 10^{-9}$
.0043	$4.0 \times 10^{-8}$
× 10 <sup>-6</sup>	$1.5 \times 10^{-11}$
× 10 <sup>-4</sup>	$5.0 \times 10^{-9}$
).036	$3.3 \times 10^{-7}$
0.99	$9.0 \times 10^{-6}$
).032	$2.9 \times 10^{-7}$
.0012	$1.1 \times 10^{-8}$
1.1	$1.0 \times 10^{-5}$
× 10 <sup>-5</sup>	$5.9 \times 10^{-10}$
1.2	$1.1 \times 10^{-5}$
48	$4.4 \times 10^{-4}$
10	$9.5 \times 10^{-5}$
49	$4.5 \times 10^{-4}$
7 × 10 <sup>-4</sup>	8.0 × 10 <sup>-9</sup>

ment/Composite Analysis

ed)

a Base entory rough y 1999 (Ci)	CLEAN SLATE 2 and 3 Inventory, FY 2000 and FY 2001 (Ci)	Mean Disposal Rate FY 2012- FY 2013 (Ci yr <sup>-1</sup> )	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (Ci m <sup>-3</sup> )
( <b>Ci)</b> ).26	6.2	0.0060	7.8	7.1 × 10 <sup>-5</sup>
		$2.6 \times 10^{-6}$	$5.2 \times 10^{-6}$	$4.7 \times 10^{-11}$
		0.0019	0.0037	$  3.3 \times 10^{-8} $
6.4	54	43	$2.0 \times 10^{2}$	0.0019

ated Inventory and Activity Concentration of Waste Disposed in U-3ah/at at re in 2013

ı Disposal Rate 1988-FY 1995 (Ci yr <sup>-1</sup> )	Mean Disposal Rate FY 1996 (Ci yr <sup>-1</sup> )	Estimated Inventory at Closure (Ci)	Estimated Mean Activity Concentration at Closure (Ci m <sup>-3</sup> )
38	38	$4.9 \times 10^{2}$	0.0018
$6.6 \times 10^{-4}$	6.6 × 10 (1)	0.015	$5.6 \times 10^{-8}$
$3.1 \times 10^{-8}$	$3.1 \times 10^{-8}$	$7.0 \times 10^{-7}$	$2.6 \times 10^{-12}$
$1.7 \times 10^{-4}$	$1.7 \times 10^{-4}$	0.0039	$1.4 \times 10^{-8}$
$7.2 \times 10^{-4}$	$7.2\times10^{-4}$	0.016	$5.9 \times 10^{-8}$
1.9 × 10 <sup>-4</sup>	$1.9 \times 10^{-4}$	0.0043	$1.6 \times 10^{-8}$
0.0013	0.0013	0.037	$1.4 \times 10^{-7}$
$6.2 \times 10^{-6}$	$6.2 \times 10^{-6}$	$4.5 \times 10^{-5}$	$1.6 \times 10^{-10}$
$3.2 \times 10^{-5}$	$3.2 \times 10^{-5}$	$6.8 \times 10^{-4}$	$2.5 \times 10^{-9}$
0.0038	0.0038	0.089	$3.2 \times 10^{-7}$
0.10	0.10	1.2	$4.4 \times 10^{-6}$
1.2	1.2	21	$7.8 \times 10^{-5}$
$4.3 \times 10^{-5}$	$4.3 \times 10^{-5}$	9.9 × 10 <sup>-4</sup>	$3.6 \times 10^{-9}$
0.0048	0.0048	0.070	$2.6 \times 10^{-7}$

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Table A2.16 Estimated Confidence Intervals for Fission and Activation Product Inventory in the U-3ax/bl and U-3ah/at Disposal Units

	Estimated 95 Percent Confide	ence Interval for Inventory (Ci)				
Nuclide	U-3ax/bl	U-3ah/at				
<sup>14</sup> C	$1.1 \times 10^{-1} - 2.8 \times 10^{0}$	$9.9 \times 10^{-3} - 1.4 \times 10^{-1}$				
<sup>36</sup> Cl	$\frac{1}{2}$ 3.0 × 10 <sup>-2</sup> - 7.5 × 10 <sup>-1</sup>	$2.6 \times 10^{-3} - 3.7 \times 10^{-2}$				
<sup>90</sup> Sr	$1.7 \times 10^2 - 5.4 \times 10^2$	$2.2 \times 10^{0}$ - $2.6 \times 10^{1}$				
<sup>99</sup> Tc	$5.9 \times 10^{-3} - 1.4 \times 10^{-1}$	$5.7 \times 10^{-4} - 6.6 \times 10^{-3}$				
<sup>137</sup> Cs	$2.8 \times 10^2 - 6.7 \times 10^2$	$2.8 \times 10^{0} - 3$				









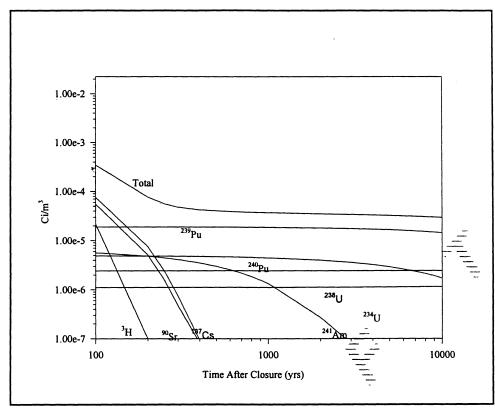


Figure A2.1 Estimated Activity Concentration of the U-3ax/bl Disposal Unit
Over Time Considering Radioactive Decay Only

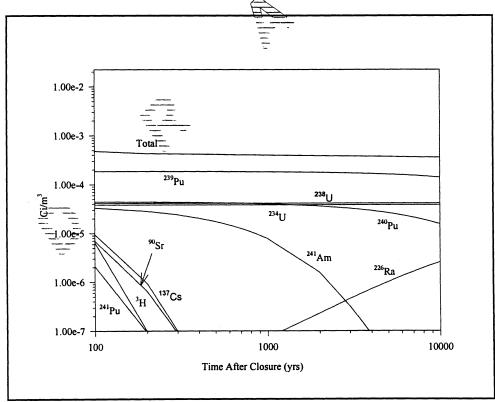


Figure A2.2 Estimated Activity Concentration of the U-3ah/at Disposal Unit Over Time Considering Radioactive Decay Only

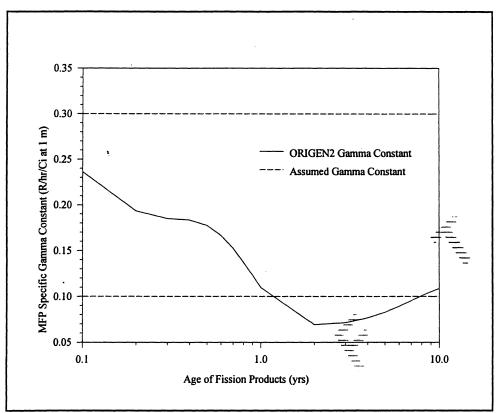


Figure A2.3 Comparison of Specific Gamma Constants for Simulated MFPs with Assumed Values as a Function of Time

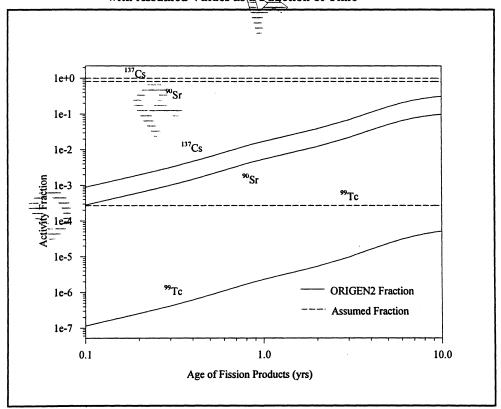


Figure A2.4 Comparison of Assumed Activity Fraction with Activity Fraction of MFPs Simulated with ORIGEN2 as a Function of Time





### **Attachment A**

### Waste Management Data Base and Low-Level Waste Inventory

**System Table Structure** 





#### Attachment A

#### Waste Management Data Base and Low-Level Waste Inventory **System Table Structure**

#### **A.1 Waste Management Data Base**

**COMBUST** 

COMBUST VIEW

COMBUST BEFORE VALIDATION

Name

Null? Type

**SHIPNO** 

NOT NULL VARCHAR2(8)

WASTE CODE

NOT NULL VARCHAR2(2)

GROSS CUBIC METERS NOT NULL NUMBER

PER COM

NOT NULL NUMBER(3)

GROSS KILOGRAMS

NOT NULL NUMBER

COMMENTS

VARCHAR2(40)



**CONTAINER** 

CONTAINER VIEW

CONTAINER BEFORE VALIDATION

Name

Null? Type



NOT NULL VARCHAR2(16)

DISPOSAL\_DATE

DATE

CONTAINER TYPE

VARCHAR2(1)

ALPHA

VÆRCHAR2(1)

**NUMERIC** 

NUMBER(2)

TIER

NUMBER(2)

LOCATION

VARCHAR2(9)

NORTH GRIE

VARCHAR2(6)

EAST GRID

VARCHAR2(6)

D3

Name

Null? Type

**SHIPNO** 

VARCHAR2(8)

LOCATION

VARCHAR2(9)

FISCAL YEAR

NUMBER(2)

WASTE CODE

VARCHAR2(2)

MIXED

VARCHAR2(1)



NUCLIDE CATEGORY VARCHAR2(1)

TIER

NUMBER(2)

ALPHA

VARCHAR2(1)

NUMERIC

NUMBER(2)

**GENERATOR** 

GENERATOR\_VIEW

GENERATOR BEFORE VALIDATION

Name

Null? Type

SHIPNO

NOT NULL VARCHAR2(8)

**GENCOD** 

NOT NULL VARCHAR2(4)

OPERATION TYPE

NOT NULL VARCHAR2(1)

GROSS\_CUBIC\_METERS NOT NULL NUMBER

NOT NULL VARCHAR2(1)

FISCAL\_YEAR

NOT NULL NUMBER(2)

FISCAL QTR

NOT NULL NUMBER(1)

ARRIVAL\_DATE

NOT NULL DATE

GROSS\_KILOGRAMS

NOT NULL NUMBER

**BURIAL** 

**NOT NULL VARCHAR2(1)** 

NUCLIDE\_CATEGORY

NOT NULL VARCHAR2(1)

GENERATED

NOT NULL VARCHAR2(1)

CURIES

NOT NULL NUMBER

DRUMS

NUMBER(4)

BOXES

NUMBER(4)

NON STAN

NUMBER(4)

**MIXED** 

NOT NULL VARCHAR2(1)

MANIFEST\_NO

VARCHAR2(5)



LWIS CONATIONER CTL

LWIS CONTAINER CTL

LWIS CONTAINER CTL VIEW

LWIS CONTAINER

LWIS CONTAINER VIEW

Name

Null? Type

CONTAINER CODE

NOT NULL NUMBER(3)

GROSS CUBIC METERS

NUMBER

CON DESC

VARCHAR2(40)



DATE DATE

VER\_CODE NOT NULL NUMBER(3)
UBIC\_METERS NOT NULL NUMBER

L\_CUBIC\_METERS NUMBER

3\_CATEGORY NOT NULL VARCHAR2(1) CODE NOT NULL VARCHAR2(2)

ILOGRAMS NOT NULL NUMBER

OGRAMS NUMBER

ST\_NO VARCHAR2(5) VARCHAR2(1)

L DATE DATE

VARCHAR2(1)

NUMBER(2) NUMBER(1) NVARCHAR2(9)

VARCHAR2(40) \_QA VARCHAR2(1)



ID INFO

ID INFO VIEW

Null? Type

STREAM\_ID NOT NULL TARCHAR2(13)

AL\_DATE NOT NULL DATE

TYPE NOT NULL VARCHAR2(5)

L\_CHAR VARCHAR2(255)
DISPOSAL VARCHAR2(255)
KNOWLEDGE VARCHAR2(1)
KNOWLEDGE VARCHAR2(1)

ASS  $\Rightarrow$  NOT NULL VARCHAR2(1) ATEGORY NOT NULL NUMBER(1)

VASTE BASIS ID NUMBER(1)

NOT NULL VARCHAR2(1)

ID\_LOW\_LEVEL\_NUCLIDE

Null? Type

TREAM\_ID NOT NULL VARCHAR2(13)

NOT NULL VARCHAR2(7)

L FORM VARCHAR2(40)

NUMBER NUMBER NUMBER

	RCHAF	Nevada Test Site
	5) [ARCH. [ARCH. [ARCH. [ARCH. [1] ] ] ] [1] ] [1] [1] [1]	AR2(13) AR2(8)
	3) (1) (1) (1) (3) (3) () (10) (10) (4) (4) (4) (4) (10) (10) (10) (10)	A2-A5

CONCENTRATION_1	VARCHAR2(10)
CONCENTRATION_2	VARCHAR2(10)
CONCENTRATION_3	VARCHAR2(10)
SURFACE_DOSE	NUMBER(9,5)
OFFSITE_MANIFEST_NO	VARCHAR2(15)
COMMENTS	VARCHAR2(240)
WS_ID	VARCHAR2(13)

MIXED\_WASTE\_NUC

MIXED\_WASTE\_NUC\_VIEW

Name

Null? Type

SHIPMENT\_NO

NOT NULL VARCHAR2(8)

PACKAGE\_NO

NOT NULL VARCHAR2(13)

NUCLIDE CURIE VARCHAR2(7)

NUMBER













## Attachment B Waste Generator Codes





			·		
	*				
				·	

#### ttachment B

#### **Generator Codes**

S

ch Institute



NTS Operations

Laboratory, Livermore, CA

CA

, IL

Laboratory, NTS Operations

Laboratory NTS Operations

pry, NTS Operations

ncy (EPA), Las Vegas

gas

(FOD/DoD), Area 12 Tunnel Complex

- a 12 Tunnel Complex
- a 12 Tunnel Complex

ering Co. (REECo), Area 5 RWMS

x/bl

RU Pad)

ion Facility

ratory

Project

nt Site		Nevada Test Site
:		
у		
Debris		
omplex		
ard		
partment		
<b>F</b> • • • • • • • • • • • • • • • • • • •		A
		$\forall$
on Project, Site 1A		
on Project, Site 2A		
on Project, Site 3C	A	
on Project, Site 3D		
on Project, <u>Sit</u> e 3E		
on Project, Site 4B		
À		
ssembly, Area 25		
nagement Project		
•		





### **Attachment C**

## Radionuclide Composition of Underground Testing Inventory



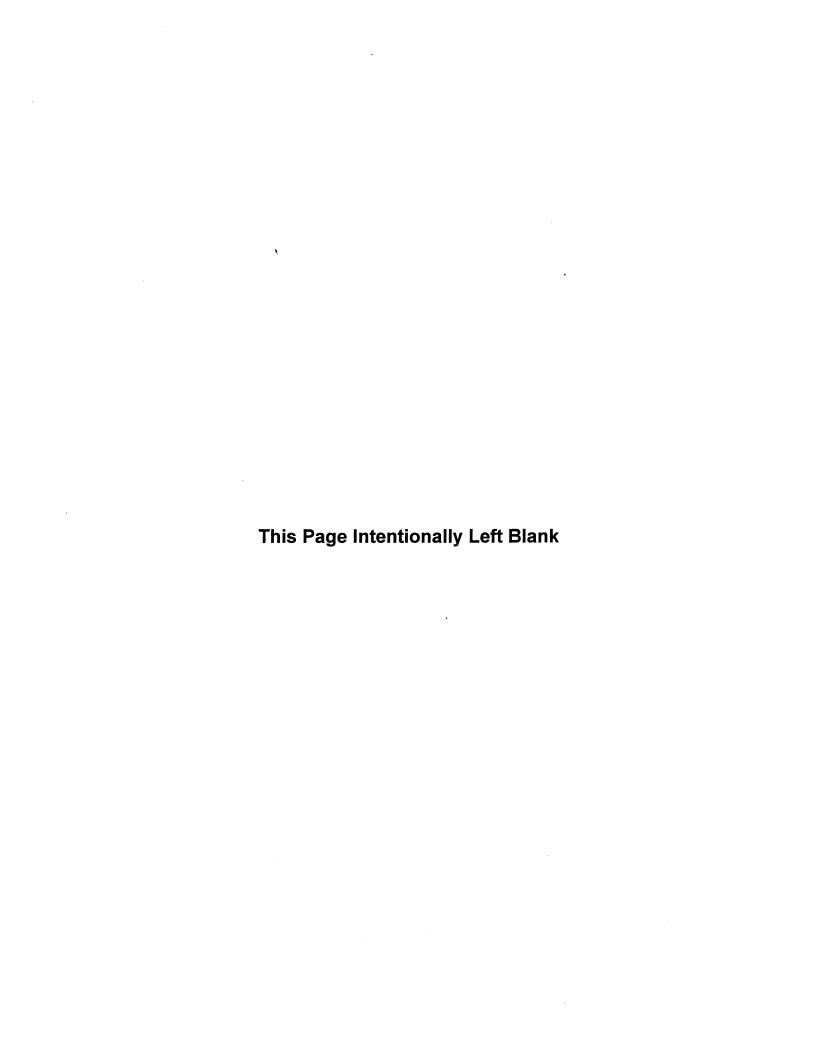


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### sting Inventory

ies (DOE/NV, 1996)

Fraction not on e Mesa"	Activity Fraction for "Pahute Mesa"
ntory	Inventory
9e-03	
5e-06 ←	1.44e-05
4e-03	₹.26e-04
9e-03	2.01e-04
1e-10	2.44e-10
5e-11	7.57e-10
5e-05	3.30e-06
1e-06	2.22e-06
5e-06	1.59e-06
9e-07	2.15e-08
3e-08	6.13e-08
1e-07	2.84e-08
6e-07	4.73e-07
9e-04	9.28e-05
7e-04	2.50e-04
3e-04	8.03e-05
6e-03	1.17e-03
0e-07	4.35e-08
6e-04	6.05e-05
3e-08	2.32e-09
5e-05	3.85e-05





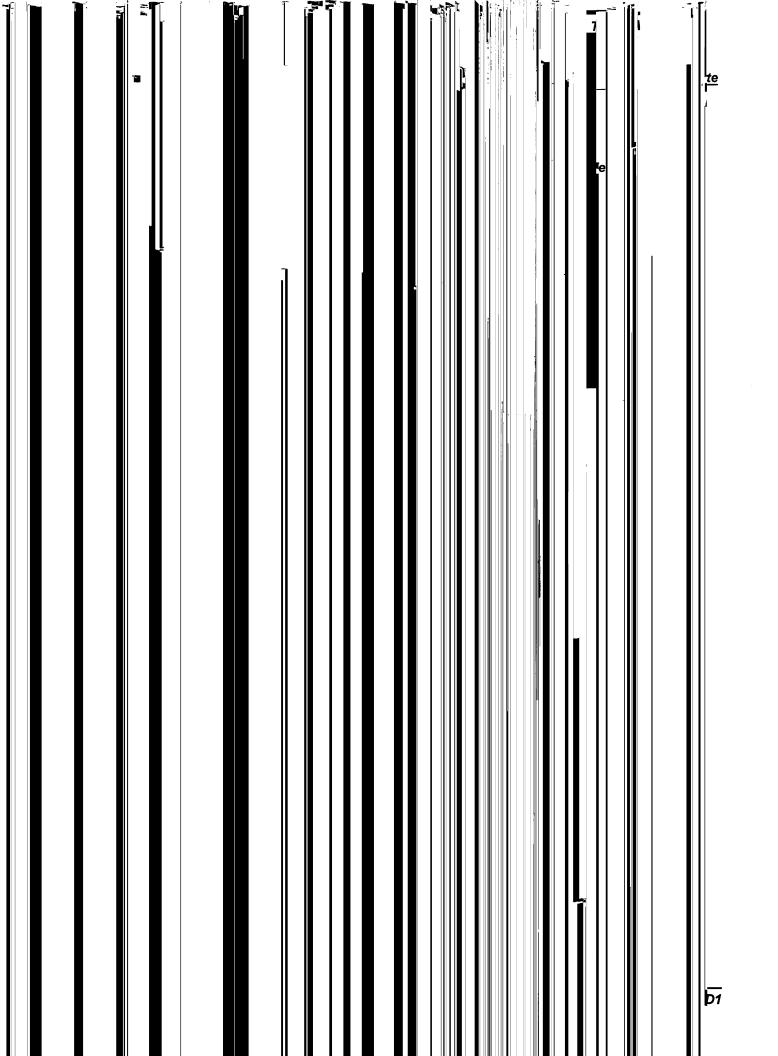


# Attachment D Projected Inventory for the U-3ax/bl Disposal Unit





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_										Ne	₽V∂	<u>ada</u>	<u>. T</u>	<u>e</u> :	<u>s</u>
	6.98E-08	8.35E-09	3.53E-09	6.98E-08	3.48E-09	6.98E-08	8.35E-09	9.31E-09	1.88E-07	6.98E-08	2.42E-06				
	6.98E-08	7.48E-09	3.14E-09	6.98E-08	3.09E-09	6.98E-08	7.48E-09	8.32E-09	1.88E-07	6.98E-08	2.42E-06				
-	6.98E-08	6.61E-09	2.75E-09	6.98E-08	2.71E-09	7.00E-08	6.61E-09	7.32E-09	1.88E-07	6.98E-08	2.42E-06				
1	6.98E-08	5.73E-09	2.35E-09	6.98E-08	2.32E-09	7.03E-08	5.73E-09	6.33E-09	1.88E-07	80-386-9	242E-060				
	€ 6.98E-08	√ 83E-09	136E-09	C 6.98E-08	1.93E-09	7.13E-08	4.83E-09	5.33E-09	1.88E-07	80-386-9	2.42E-06				
+	6.98E-08	3.93E-09√∭	1.578-09-V	80-386-9	1.54E-09	7.38E-08	3.93E-09	4.34E-09	1.88E-07	6.98E-08	2.42E-06				
-	6.98E-08	3.03E-09	1.17E-09	6.98E-08	1.15E-09	8.03E-08	3.03E-09	3.34E-09	1.88E-07	6.98E-08	2.42E-06				
	6.98E-08	2.57E-09	9.71E-10	6.98E-08	9.58E-10	8.68E-08	2.57E-09	2.85E-09	1.88E-07	80-386-9	2.42E-06				
1	6.98E-08	2.11E-09	7.73E-10	6.98E-08	7.63E-10	9.73E-08	2.11E-09	2.35E-09	1.88E-07	6.98E-08	2.42E-06				
	6.98E-08	1.18E-09	3.79E-10	6.98E-08	3.73E-10	1.42E-07	1.18E-09	1.35E-09	1.88E-07	6.98E-08	2.42E-06				
	6.50E-08	2.45E-10	3.32E-11	6.50E-08	3.27E-11.	2.52E-07	2.45E-10	3.55E-10	1.88E-07	6.98E-08	2.42E-06				
* > > > > > > > > > > > > > > > > > > >	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01	9.57E-11	0.00E+01	6.98E-08	0.00E+01				
7	RA228	AC225	AC227	\C228	TH227	TH228	TH229	TH230	TH231	TH232	TH234				

Neva	da	Test	Site



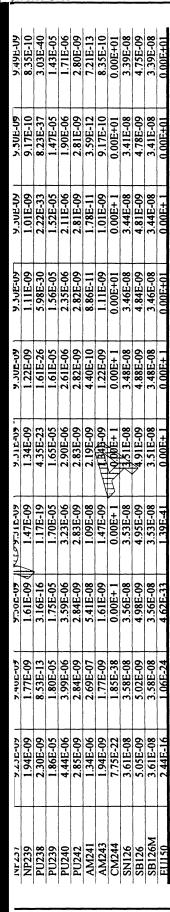
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Activity Concentration of U-3ax/bl as a Function of Time Considering Only Radioactive Decay and Ingrowth Table A2.D.2

					Elapsed Time Since Closure	Since Closure				
Z. I. C. L. Z.	1000 Yrs	2000 Yrs	3000 Yrs	4000 Yrs	5000 Yrs	6000 Yrs	7000 Yrs	8000 Yrs	9000 Yrs	1.0E+04 Yrs
ואמכוומב	(Ci/m³) =	(CI/m³)	(Ci/m³)	(Ci/m³)	(Ci/m)	(Ci/m²)	(Ci/m²)	(Ci/m³) —	(Ci/m²)	(Ci/m³)
C14	4.91E-07	4.35E-97	3.85E-07	3.41E-07	3.03E-07	2.68E-07	2.38E-07	2.10E-07	1.86E-07	1.65E-07
AL 26	2.63E-11	2,63E-HIN	2.62E-11	2.62E-11	2.62E-11	2.62E-11	2.61E-11	2.61E-11	2.61E-11	2.60E-11
CL 36	1.49E-07	<b>(II.48E-07</b> )	1.48E-07	1.48E-07	1.47E-07	1.47E-07	1.47E-07	1.46E-07	1.46E-07	1.46E-07
AR 39	4.71E-08	3.\$8E-09	2.72E-10	2.07E-11	1.57E-12	1.20E-13	9.08E-15	6.91E-16	5.25E-17	3.99E-18
K 40	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07
CA 41	1.41E-06	1.40E-06	1.38E-06	1.37E-06	1.36E-06	1.35E-06	1.34E-06	1.33E-06	1.31E-06	1.30E-06
NI 59	2.58E-08	2.56E-08	2.53E-08	2.51E-08	2.49E-08	2.47E-08	2.45E-08	2.43E-08	2.41E-08	2.39E-08
NI 63	1.60E-09	8.56E-13	4.58E-16	2.45E-19	1.31E-22	6.99E-26	3.73E-29	2.00E-32	1.07E-35	5.70E-39
SR 90	2.74E-14	1.26E-24	5.79E-35	0.00E+1	0.00E+1	0.00E+1	0.00E+1	0.00E+1	0.00E+01	0.00E+01
V 90	2.74E-14	1.26E-24	5.79E-35	(IX) 0.00E+1	0.00E+1	0.00E+1	0.00E+1	0.00E+1	0.00E+01	0.00E+01
ZR 93	3.95E-08	3.95E-08	3.94E-08	3.94E-08	3.94E-08	3.94E-08	3.94E-08	3.94E-08	3.93E-08	3.93E-08
NB 93M	3.75E-08	3.75E-08	3.75E-08	1 (11) 3.75E-08	3.74E-08	3.74E-08	3.74E-08	3.74E-08	3.74E-08	3.74E-08
NB 94	1.23E-07	1.19E-07	1.15E-07	/ 1.11E-07	1.07E-07	1.04E-07	1.00E-07	9.70E-08	9.37E-08	9.06E-08
TC 99	2.85E-07	2.84E-07	2.83E-07	2.82E-07	2.81E-07	2.80E-07	2.80E-07	2.79E-07	2.78E-07	2.77E-07
PD107	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09	1.35E-09
SN121M	7.39E-12	2.49E-17	8.36E-23	2.81E-28	9.45E-34	3.18E-39	0.00E+01	0.00E+1	0.00E+01	0.00E+01
1129	8.27E-10	8.27E-10	8.26E-10	8.26E-10	8.26E-10	8.26E-10	8.26E-10	8.26E-10	8.26E-10	8.26E-10
CS135	2.97E-08	2.97E-08	2.97E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08
CS137	7.05E-14	6.51E-24	6.01E-34	0.00E+1	1+300E+1	0.00E+1	0.00E+01	0.00E+1	0.00E+01	0.00E+01
BA137M	6.67E-14	6.16E-24	6.20E-34	0.00E+1		0.00E+1	0.00E+01	0.00E+1	0.00E+01	0.00E+01
SM148	1.26E-31	2.50E-31	3.75E-31	5.00E-31	6.25E-31	7.50E-31	8.74E-31	9.99E-31	1.12E-30	1.25E-30
SM151	1.76E-08	7.97E-12	3.60E-15	1.63E-18	7.35E-22	3.32E-25	1.50E-28	6.78E-32	3.06E-35	1.38E-38
EU152	1.02E-21	0.00E+01	0.00E+1	0.00E+ 1	0.00E+1	0.00E+1	0.00E+01	0.00E+1	0.00E+01	0.00E+01
GD152	1.44E-18	1.44E-18	1.44E-18	1.44E-18	1.44E-18	1.44E-18	1.44E-18	1.44E-18	1.44E-18	1.44E-18
M9910H	4.56E-12	2.56E-12	1.44E-12	8.06E-13	4.52E-13	2.54E-13	1.43E-13	8.00E-14	4.49E-14	2.52E-14
TL207	3.91E-09	7.88E-09	1.16E-08	1.53E-08	1.89E-08	2.25E-08	2.59E-08	2.93E-08	3.27E-08	3.59E-08
TL208	2.51E-08	2.51E-08	2.51E-08	2.51E-08	2.51E-08	2.54月508人	2.51E-08	2.51E-08	2.51E-08	2.51E-08
TL209	1.99E-10	3.74E-10	5.33E-10	6.76E-10	8.06E-10	4.04B310 V	> 1.03E-09	1.13E-09	1.21E-09	1.29E-09
PB209	9.20E-09	1.73E-08	2.47E-08	3.13E-08	3.73E-08	4.28E-08	4.77E-08	5.21E-08	5.61E-08	5.97E-08
PB210	1.89E-09	6.78E-09	1.34E-08	2.11E-08	2.95E-08	3.84E-08	4.75E-08	5.68E-08	6.62E-08	7.56E-08
PB211	3.92E-09	7.90E-09	1.17E-08	1.54E-08	1.90E-08	2.25E-08	2.60E-08	2.94E-08	3.28E-08	3.60E-08
PB212	6.98E-08	80-386-9	6.98E-08	6.98E-08	6.98E-08	6.98E-08	6.98E-08	6.98E-08	6.98E-08	6.98E-08
PB214	2.00E-09	6.78E-09	1.34E-08	2.11E-08	2.95E-08	3.84E-08	4.75E-08	5.68E-08	6.62E-08	7.56E-08
BI210	1.89E-09	6.78E-09	1.34E-08	2.11E-08	2.95E-08	3.84E-08	4.75E-08	↑ 5.68E-08	6.62E-08	7.56E-08
B1211	3.92E-09	7.90E-09	1.17E-08	1.54E-08	1.90E-08	2.25E-08	2.60E-08	> \\ 2.94E-08	3.28E-08	3.60E-08
							1	NA NA		

		1.02.0   1











## Attachment E Projected Inventory for the U-3ah/at Disposal Unit





A2-E1
TI ON TOP 1 OF THE WAY AND A STATE OF THE ST

Nev	/ada	Test	Site

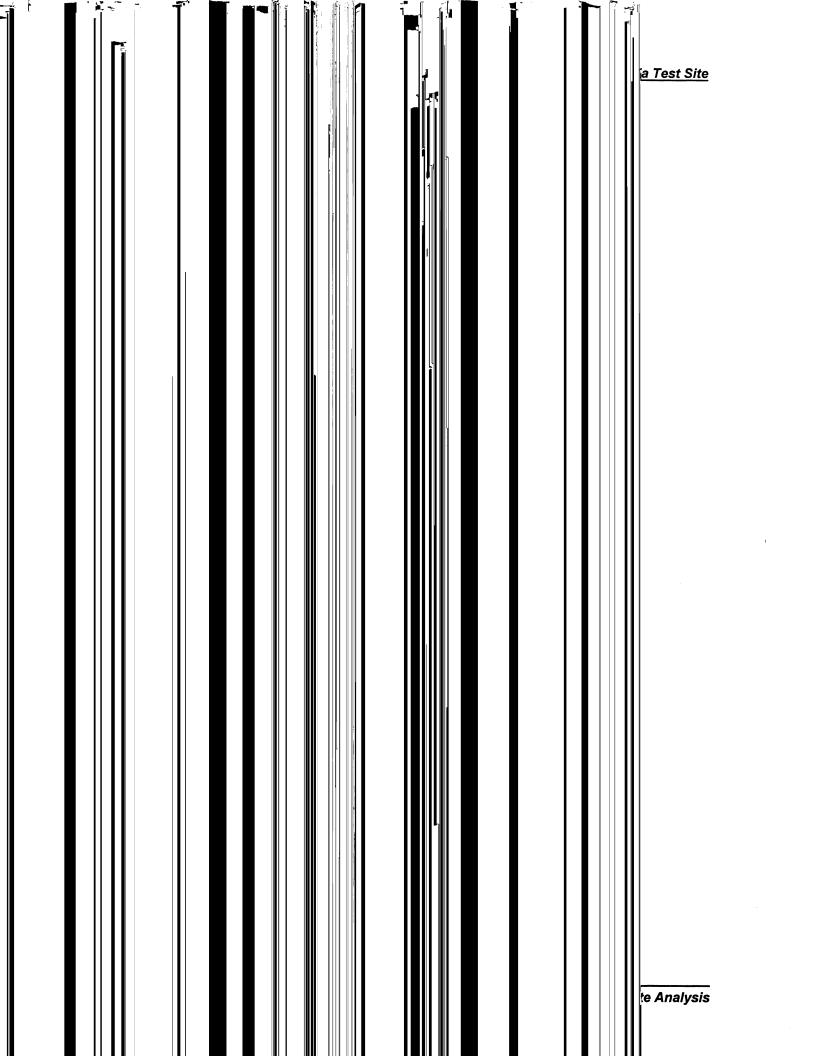
IE-08	3E-07	7E-08	1E-08	3E-08	1E-08	3E-07	3E-07	1.23E-06	IE-08	3E-05	
3.01	1.2	2.2.	3.01	2.2	3.0	1.2	3.28	1.23	3.01	4.3	
3.01E-08	1.10E-07	2.01E-08	3.01E-08	1.98E-08	3.01E-08	1.10E-07	2.92E-07	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	9.68E-08	1.75E-08	3.01E-08	1.73E-08	3.01E-08	80-389.6	2.56E-07	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	8.36E-08	1.50E-08	3.01E-08	1.48E-08	3.02E-08	8.36E-08	2.20E-07	1.23E-06	3.01E-08	4.33E-05	<u> </u>
3.01E-08	7.03E-08	1.04E-08	80-AINO:6	(182E-08	3.03E-08	7.03E-08	1.84E-07	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	5.68E-08	9.84E-09	3.01E-08	9.70E-09	3.06E-08	5.68E-08	1.48E-07	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	4.32E-08	7.26E-09	3.01E-08	7.16E-09	3.13E-08	4.32E-08	1.12E-07	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	3.64E-08	5.96E-09	3.01E-08	5.88E-09	3.20E-08	3.64E-08	9.43E-08	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	2.95E-08	4.67E-09	3.01E-08	4.61E-09	3.32E-08	2.95E-08	7.63E-08	1.23E-06	3.01E-08	4.33E-05	
3.01E-08	1.56E-08	2.10E-09	3.01E-08	2.08E-09	3.82E-08	1.56E-08	4.02E-08	1.23E-06	3.01E-08	4.33E-05	
1.86E-08	1.62E-09	6.15E-11	1.86E-08	6.08E-11	3.39E-08	1.62E-09	4.15E-09	1.23E-06	3.01E-08	4.33E-05	
RA228	AC225	AC227	AC228	TH227	TH228	TH229	TH230	TH231	TH232	TH234	

nce Assessment/Composite Analysis

Table A2.E.1 (continued)

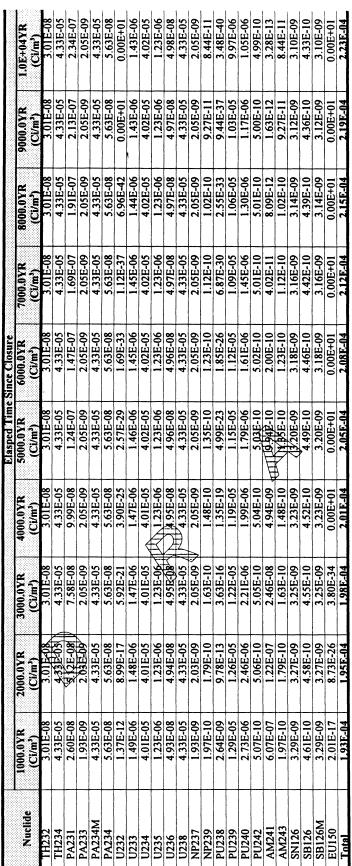
	Closure					Elapsed Time	Elapsed Time Since Closure				
Nuclide	2013	100.0YR	200.0YR	250.0YR	300.0YR	400.0YR	S00.0YR	600.0YR	700.0YR	800.0YR	900.0YR
	(CI/m³)	(Ci/m²)	(Ci/m³)	(Ci/m³)	(Ci/m³)	(Ci/m³)	(Ci/m³)	(Ci/m³)	(CI/m³)	(Ci/m²)	(CI/m³)
PA231	3.00E-10	1.90E-09 √	√ 5.48E-09	6.78E-09	8.07E-09	1.06E-08	1.32E-08	1.58E-08	1.83E-08	2.09E-08	2.35E-08
PA233	1.45E-09	1.53E-09	\\1.61E-09	1.64E-09	1.68E-09	1.73E-09	1.78E-09	1.82E-09	1.85E-09	1.88E-09	1.91E-09
PA234M	4.33E-05	4.33H-05	/ 14.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05
PA234	5.63E-08	5.63E-08	JV 5.63E-08	5.63E-08	5.63E-08	5.63E-08	5.63E-08	5.63E-08	5.63E-08	5.63E-08	5.63E-08
U232	2.07E-08	7.91E-09	3.02E-09	1.87E-09	1.15E-09	4.40E-10	1.68E-10	6.42E-11	2.45E-11	9.36E-12	3.57E-12
U233	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06	1.49E-06
U234	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05	4.01E-05
U235	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06	1.23E-06
U236	4.92E-08	4.92E-08	4.93E-08	4.93E-08	4.93E-08	4.93E-08	4.93E-08	4.93E-08	4.93E-08	4.93E-08	4.93E-08
U237	4.44E-10	3.60E-12	2.92E-14	2 desens	2.37E-16	1.93E-18	1.56E-20	1.27E-22	1.03E-24	8.11E-27	0.00E+01
U238	4.33E-05	4.33E-05	4.33E-05	SO 2000 (1)	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05	4.33E-05
NP237	1.45E-09	1.53E-09	1.61E-09		1.68E-09	1.73E-09	1.78E-09	1.82E-09	1.85E-09	1.88E-09	1.91E-09
NP239	2.16E-10	2.14E-10	2.12E-10	%/11E-10	2.10E-10	2.08E-10	2.06E-10	2.04E-10	2.02E-10	2.00E-10	1.98E-10
PU238	7.11E-06	3.23E-06	1.47E-06	9.87E-07	6.65E-07	3.02E-07	1.37E-07	6.22E-08	2.82E-08	1.28E-08	5.81E-09
PU239	1.33E-05	1.33E-05	1.32E-05	1.32E-05	1.32E-05	1.32E-05	1.31E-05	1.31E-05	1.30E-05	1.30E-05	1.30E-05
PU240	3.04E-06	3.01E-06	2.98E-06	2.96E-06	2.94E-06	2.91E-06	2.88E-06	2.85E-06	2.82E-06	2.79E-06	2.76E-06
PU241	1.81E-05	1.47E-07	1.19E-09	1.07E-10	9.67E-12	7.85E-14	6.37E-16	5.17E-18	4.07E-20	0.00E+01	0.00E+01
PU242	5.08E-10	5.08E-10	5.08E-10	5.08E-10	5.08E-10	\$.07E-10	5.07E-10	5.07E-10	5.07E-10	5.07E-10	5.07E-10
AM241	2.40E-06	2.57E-06	2.19E-06	2.02E-06	1.87E:161	1.59E-06	1.35E-06	1.15E-06	9.83E-07	8.37E-07	7.13E-07
AM243	2.16E-10	2.14E-10	2.12E-10	2.11E-10	2.10E-X07	/ 2.08E-10	2.06E-10	2.04E-10	2.02E-10	2.00E-10	1.98E-10
CM244	1.06E-07	2.31E-09	5.02E-11	7.41E-12	1.09E-12/	2.38E-14	5.18E-16	1.13E-17	2.44E-19	6.48E-21	0.00E+01
CD113M	3.99E-08	3.45E-10	2.98E-12	2.77E-13	2.57E-14	2.22E-16	1.92E-18	1.80E-20	1.50E-21	0.00E+01	0.00E+01
SN126	3.32E-09	3.32E-09	3.31E-09	3.31E-09	3.31E-09	3.31E-09	3.31E-09	3.30E-09	3.30E-09	3.30E-09	3.30E-09
SB126	4.64E-10	4.64E-10	4.64E-10	4.64E-10	4.63E-10	4.63E-10	4.63E-10	4.62E-10	4.62E-10	4.62E-10	4.62E-10
SB126M	3.32E-09	3.32E-09	3.31E-09	3.31E-09	3.31E-09	3.31E-09	3.31E-09	3.30E-09	3.30E-09	3.30E-09	3.30E-09
EU150	4.63E-09	6.74E-10	9.83E-11	3.76E-11	1.43E-11	2.09E-12	3:05E-13	4.45E-14	6.48E-15	9.45E-16	1.38E-16
Total	2.39E-03	2.39E-04	1.99E-04	1.96E-04	1.95E-04	1.94E-04	11.93 K-04	1.93E-04	1.93E-04	1.93E-04	1.93E-04





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Table A2.E.2 (continued)







### **Attachment F**

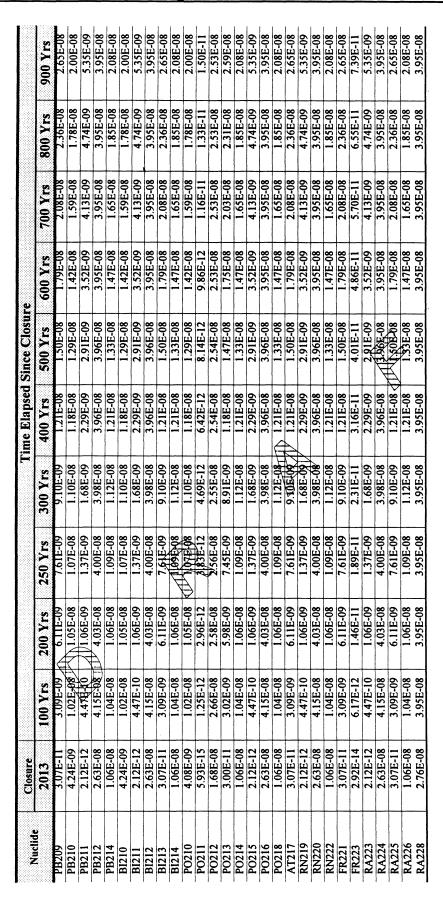
**Projected Inventory for the U-3bh Disposal Unit** 

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2.88E-10         5.58E-16         1.08E-21         0.00E+01	CA 41	2.98E-08	2.98E-08	2.97E-08	2.97E-08	2.97E-08	2.97E-08	2.97E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08
5.47E-10         5.46E-10         5.45E-10         1.75E-08         3.35E-10         3.35E-10         3.35E-10         3.35E-11         1.25E-12         1.65E-12         1.65E-13         1.65E-13         1.65E-13         1.65E-13         1.65E-13         1.66E-13	09 00	2.88E-10	5.58E-16	1.08E-21	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01	0.00E+01
7.65E-08         3.60E-08         1.70E-08         1.70E-08         1.70E-09         1.70E-08         1.70E-09         1.70E-09         1.70E-09         1.70E-09         1.70E-09         1.70E-09         1.70E-09         1.70E-17         1.70E-17         1.70E-01         3.35E-10         3.92E-10           2.17E-05         2.01E-06         1.80E-07         \$\$\begin{array}{c} \text{5.00} \text{3.00E-09} \text{3.00E-09} \text{1.47E-10} \text{1.36E-11} \text{1.36E-11} \text{1.26E-12} \te	NI 59	5.47E-10	5.46E-10	5.46E-10	5.45E-10	5.45E-10	5.45E-10	5.44E-10	5.44E-10	5.43E-10	5.43E-10	5.42E-10
1.73E-06   2.70E-09   4.19E-12   165E-13   6.52E-15   1.02E-17   1.71E-20   2.16E-21   1.69E-21   1.72E-06   2.17E-05   2.01E-06   1.86E-07   56E-08   1.72E-08   1.59E-09   1.47E-10   1.36E-11   1.26E-12   1.26E-12   1.22E-10   7.92E-10   7	NI 63	7.65E-08	3.60E-08	1.70E-08	1.16E-08	7.98E-09	3.76E-09	1.77E-09	8.33E-10	3.92E-10	1.85E-10	8.69E-11
2.17E-05         2.01E-06         1.86E-07         584E/98         1.72E-08         1.59E-09         1.47E-10         1.36E-11         1.26E-12           2.17E-05         2.01E-06         1.86E-07         566E-08         1.72E-10         7.92E-10         7.92	KR 85	1.73E-06	2.70E-09	4.19E-12	1 65EN3	6.52E-15	1.02E-17	1.71E-20	2.16E-21	1.69E-21	1.33E-21	1.04E-21
2.17E-05         2.01E-06         1.86E-07         \$\begin{array}{c} \text{5} \text{0} \text{6} \text{1.72E-09} \text{1.72E-10} \text{7.92E-10} \text{7.92E-11} \text{7.92E-12} \text{7.92E-10} 7.92E-	SR 90	2.17E-05	2.01E-06	1.86E-07	S) 65E-08	1.72E-08	1.59E-09	1.47E-10	1.36E-11	1.26E-12	1.17E-13	1.08E-14
7.92E-10         7.92E-11         7.92E-11         7.92E-11         7.92E-11         7.92E-11         7.92E-11         7.92E-11         7.93E-11	V 90	2.17E-05	2.01E-06	1.86E-07	\$166E-08	1.72E-08	1.59E-09	1.47E-10	1.36E-11	1.26E-12	1.17E-13	1.08E-14
8.94E-08         1.30E-09         7.56E-10         7.53E-10         7.53E-11         7.53E-11         7.73E-11	ZR 93	7.92E-10	7.92E-10	7.92E-10	7/92E-10	7.92E-10	7.92E-10	7.92E-10	7.92E-10	7.92E-10	7.92E-10	7.92E-10
2.69E-09         2.68E-09         2.67E-09         2.66E-09         2.65E-09         2.64E-09         2.65E-09         2.62E-09         2.63E-11         2.73E-11         2.73E-12         2.73E-13         2.73E-13         2.73E-13         2.73E-13         2.73E-13         2.73E-13         2.73E-13         2.73E-13	NB 93M	8.94E-08	1.30E-09	7.56E-10	7.53E-10	7.53E-10	7.53E-10	7.53E-10	7.53E-10	7.53E-10	7.52E-10	7.52E-10
1.33E-08   1.33E-11   2.73E-11   1.56E-11	NB 94	2.69E-09	2.68E-09	2.67E-09	2.67E-09	2.66E-09	2.65E-09	2.64E-09	2.63E-09	2.62E-09	2.62E-09	2.61E-09
2.73E-11         2.73E-10         2.73E-10         2.73E-10         2.73E-10         2.73E-10         2.73E-10         2.73E-10         2.73E-10         2.73E-11         2.73E-11         2.73E-11         2.73E-11         2.73E-12	TC 99	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08	1.33E-08
6.55E-08         1.64E-08         4.09E-09         1.02E-09         2.55E-10         6.38E-11         1.59E-11         3.98E-12           1.66E-11         1.	PD107	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11	2.73E-11
1.66E-11	SNI2IM	6.55E-08	1.64E-08	4.09E-09	2.04E-09	1.02E-09-	7), 2.55E-10	6.38E-11	1.59E-11	3.98E-12	9.94E-13	2.48E-13
5.96E-10         5.96E-11         2.79E-12         2.79E-09         2.79E-09         2.79E-11         2.79E-12         2.79E-11         2.79E-12         2.79E-10         2.79E-11         2.75E-11         2.75E-11         2.75E-12         2.79E-12         2.79E-09	1129	1.66E-11	1.66E-11	1.66E-11	1.66E-11	1.66E/K	/ 1.66E-11	1.66E-11	1.66E-11	1.66E-11	1.66E-11	1.66E-11
2.85E-05         2.81E-05         2.81E-07         8.85E-08         2.79E-08         2.76E-09         2.74E-10         2.72E-11         2.70E-12           2.70E-05         2.68E-06         2.66E-07         8.37E-08         2.64E-08         2.62E-09         2.59E-10         2.57E-11         2.55E-12           9.48E-07         4.39E-07         2.03E-07         1.38E-07         9.40E-08         4.35E-09         2.05E-09         2.59E-10         2.55E-12           8.38E-07         5.13E-09         3.14E-11         2.45E-12         1.92E-13         1.17E-15         7.19E-18         4.33E-09         4.33E-09           6.30E-07         1.99E-10         6.29E-14         1.12E-15         1.99E-17         6.28E-21         1.96E-13         1.98E-31           1.52E-21         3.08E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20           2.16E-12         1.68E-13         1.46E-13         1.46E-13         1.46E-13         1.14E-13         1.14E-13         1.14E-09         3.14E-09         3.11E-09           2.16E-12         4.46E-10         1.66E-09         1.46E-13         1.45E-08         1.45E-08         1.45E-08         1.45E-08         1.45E-08           2.44E-09         1.45E-08 <td< td=""><td>CS135</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-19</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-10</td><td>5.96E-10</td></td<>	CS135	5.96E-10	5.96E-10	5.96E-10	5.96E-10	5.96E-19	5.96E-10	5.96E-10	5.96E-10	5.96E-10	5.96E-10	5.96E-10
2.70E-05         2.68E-06         2.66E-07         8.37E-08         2.64E-08         2.62E-09         2.59E-10         2.57E-11         2.55E-12           9.48E-07         4.39E-07         2.03E-07         1.38E-07         9.40E-08         4.35E-08         2.02E-08         9.33E-09         4.32E-09           8.38E-07         5.13E-09         3.14E-11         2.45E-12         1.92E-13         1.17E-15         7.19E-18         4.53E-20         1.34E-21           6.30E-07         1.99E-10         6.29E-14         1.12E-15         1.99E-10         6.28E-21         1.99E-20         3.09E-20	CS137	2.85E-05	2.83E-06	2.81E-07	8.85E-08	2.79E-08	2.76E-09	2.74E-10	2.72E-11	2.70E-12	2.68E-13	2.66E-14
948E-07         4.39E-07         2.03E-07         1.38E-07         9.40E-08         4.35E-08         2.02E-08         9.33E-09         4.32E-09           8.38E-07         5.13E-09         3.14E-11         2.45E-12         1.92E-13         1.17E-15         7.19E-18         4.53E-20         1.34E-21           6.30E-07         1.99E-10         6.29E-14         1.12E-15         1.99E-17         6.28E-21         1.99E-24         6.27E-28         1.98E-31           1.52E-21         3.08E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20           1.68E-13         1.50E-13         1.42E-13         1.34E-13         1.19E-13         1.12E-13           2.11E-12         4.46E-10         1.06E-09         1.67E-09         2.29E-09         3.51E-09         4.12E-09           9.44E-09         1.49E-08         1.44E-08         1.43E-08         1.42E-08         1.42E-08         1.42E-08           6.67E-13         1.37E-10         1.57E-10         1.57E-10         2.61E-10         3.24E-10         4.49E-10	BA137M	2.70E-05	2.68E-06	2.66E-07	8.37E-08	2.64E-08	2.62E-09	2.59E-10	2.57E-11	2.55E-12	2.53E-13	2.51E-14
8.38E-07         5.13E-09         3.14E-11         2.45E-12         1.92E-13         1.17E-15         7.19E-18         4.53E-20         1.34E-21           6.30E-07         1.99E-10         6.29E-14         1.12E-15         1.99E-17         6.28E-21         1.99E-24         6.27E-28         1.98E-31           1.52E-21         3.08E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20           1.52E-13         1.56E-13         1.46E-13         1.42E-13         1.34E-13         1.19E-13         1.12E-13           2.11E-12         4.46E-10         1.06E-09         1.67E-09         2.29E-09         2.90E-09         3.51E-09         4.12E-09           9.44E-09         1.49E-08         1.44E-08         1.42E-08         1.42E-08         1.42E-08         1.42E-08           6.67E-11         1.32E-13         1.32E-10         3.24E-10         3.24E-10         3.87E-10         4.49E-10	SM151	9.48E-07	4.39E-07	2.03E-07	1.38E-07	9.40E-08	4.35E-08	2.02E-08	9.33E-09	4.32E-09	5.00E-09	9.25E-10
6.30E-07         1.99E-10         6.29E-14         1.12E-15         1.99E-17         6.28E-21         1.99E-24         6.27E-28         1.98E-31           1.52E-21         3.08E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20         3.09E-20           1.52E-21         1.58E-13         1.50E-13         1.46E-13         1.42E-13         1.34E-13         1.19E-13         1.12E-13           2.11E-12         4.46E-10         1.06E-09         1.56E-09         1.67E-09         2.29E-09         2.90E-09         3.51E-09         4.12E-09           9.44E-09         1.49E-08         1.44E-08         1.42E-08         1.42E-08         1.42E-08         1.42E-08         1.42E-08           6.67E-11         1.32E-10         1.56E-10         2.61E-10         3.24E-10         3.87E-10         4.49E-10	EU152	8.38E-07	5.13E-09	3.14E-11	2.45E-12	1.92E-13	1.17E-15	7.19E-18	4.53E-20	1.34E-21	1.42E-21	1.50E-21
M         1.52E-21         3.08E-20         3.09E-20         3.09E-30         3.	EU154	6.30E-07	1.99E-10	6.29E-14	1.12E-15	1.99E-17	6.28E-21	1,99E-24	6.27E-28	1.98E-31	6.27E-35	1.98E-38
M         1.68E-13         1.59E-13         1.46E-13         1.45E-13         1.34E-13         1.19E-13         1.19E-13         1.12E-13           2.11E-12         4.46E-10         1.06E-09         1.67E-09         2.29E-09         2.90E-09         3.51E-09         4.12E-09           9.44E-09         1.49E-08         1.45E-08         1.44E-08         1.42E-08         1.42E-08         1.42E-08           6.67E-13         1.32E-10         1.64E-10         1.97E-10         2.61E-10         3.24E-10         3.87E-10         4.49E-10	GD152	1.52E-21	3.08E-20	3.09E-20	3.09E-20	3.09E-20	3.09E-20	13.09E-20	3.09E-20	3.09E-20	3.09E-20	3.09E-20
2.11E-12         4.46E-10         1.06E-09         1.36E-09         1.67E-09         2.29E-09         2.96E-09         3.51E-09         4.12E-09           9.44E-09         1.49E-08         1.45E-08         1.44E-08         1.42E-08         1.42E-08         1.42E-08         1.42E-08           6.64E-13         6.66E-11         1.32E-10         1.64E-10         1.97E-10         2.61E-10         3.24E-10         3.87E-10         4.49E-10	M9910H	1.68E-13	1.59E-13	1.50E-13	1.46E-13	1.42E-13	1.34E-13 <	CK-ROXI)	1.19E-13	1.12E-13	1.06E-13	1.00E-13
9.44E-09 1.49E-08 1.45E-08 1.44E-08 1.42E-08 1.42E-10 1.42E-08 1.42E-10 1.42E-08 1.42E-10 1.42E-08 1.42E-10 1.42E-10 1.42E-08 1.42E-10 1.4	TL207	2.11E-12	4.46E-10	1.06E-09	1.36E-09	1.67E-09	2.29E-09	2.90E-09	3.51E-09	4.12E-09	4.73E-09	5.34E-09
6 67F-13 6 66F-11 132F-10 164F-10 197E-10 2.61E-10 3.24E-10 4.49E-10 4.49E-10	TL208	9.44E-09	1.49E-08	1.45E-08	1.44E-08	1.43E-08	1.42E-08	1.42E-08	1.42E-08	1.42E-08	1.42E-08	1.42E-08
C1 750.0	TL209	6.63E-13	6.66E-11	1.32E-10	1.64E-10	1.97E-10	2.61E-10	3.24E-10	3.87E-10	4.49E-10	5.11E-10	5.72E-10



Fable A2.F.1 (continued)





A2-F2

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1.29E-08	2.73E-11	0.00E+01	1.66E-11	5.95E-10	0.00E+01	0.00E+01	2.67E-32	3.34E-40	0.00E+01	3.09E-20	5.22E-16	5.62E-08	1.42E-08	4.19E-09	1.94E-07	6.09E-07	5.63E-08	3.95E-08	6.09E-07	6.09E-07	5.63E-08	3.95E-08	1.94E-07
1.29E-08	2.73E-11	0.00E+01	1.66E-11	5.95E-10	0.00E+01	0.00E+01	2.41E-32	7.44E-37	0.00E+01	3.09E-20	9.30E-16	5.10E-08	1.42E-08	3.94E-09	1.82E-07	5.34E-07	5.12E-08	3.95E-08	5.34E-07	5.34E-07	5.12E-08	3.95E-08	1.82E-07
1.30E-08	2.73E-11	0.00E+01	1.66E-11	5.95E-10	0.00E+01	0.00E+01	2.14E-32	1.65E-33	0.00E+01	3.09E-20	1.66E-15	4.58E-08	1.42E-08	3.65E-09	1.69E-07	4.59E-07	4.59E-08	3.95E-08	√ 4.59E-07	(1,4.59E-07	4.59E-08	3.95E-08	1.69E-07
1.30E-08	2.73E-11	0.00E+01	1.66E-11	5.95E-10	0.00E+01	0.00E+01	1.87E-32	3.65E-30	0.00E+01	3.09E-20	2.95E-15	4.05E-08	1.42E-08	3.34E-09	1.55E-07	3.85E-07	4.06E-08	3.95E-08	3.85E-07	3.85E-07	4.06E-98	3.95E-08	1.55E-07
1.30E-08	2.73E-11	0.00E+01	1.66E-11	5.95E-10	0.00E+01	0.00E+01	1.60E-32	8.07E-27	0.00E+01	3.09E-20	5.26E-415	3.508-08-11	ALAZEOR V	3.00E-09	1.39E-07	3.11E-07	3.51E-08	3.95E-08	3.11E-07	3.11E-07	3.51E-08	3.95E-08	1.39E-07
1.31E-08	2.73E-11	4.97E-38	1,66E-11	01-3965	0,00E+01	(0,00E+01	1.33E-32	1.79E-23	0.00E+01	3.09E-20	9.37E-15	2.95E-08	1.42E-08	2.61E-09	1.21E-07	2.40E-07	2.96E-08	3.95E-08	2.40E-07	2.40E-07	2.96E-08	3.95E-08	1.21E-07
1.31E-08	2.73E-11	5.26E-32	1.66E-11	\$.96E-10 ←	0.00E+01	0.00E+01	1.07E-32	3.95E-20	0.00E+01	3.09E-20	1.67E-14	2.38E-08	1.42E-08	2.19E-09	1.01E-07	1.73E-07	2.39E-08	3.95E-08	1.73E-07	1.73E-07	2.39E-08	3.95E-08	1.01E-07
1.32E-08	2.73E-11	5.55E-26	1.66E-11	5.96E-10	2.25E-35	0.00E+01	7.98E-33	8.75E-17	0.00E+01	3.09E-20	2.97E-14	1.80E-08	1.42E-08	1.72E-09	7.97E-08	1.12E-07	1.81E-08	3.95E-08	1.12E-07	1.12E-07	1.81E-08	3.95E-08	7.97E-08
1.32E-08	2.73E-11	5.87E-20	1.66E-11	5.96E-10	2.43E-25	2.30E-25	5.30E-33	1.94E-13	0.00E+01	3.09E-20	5.30E-14	1.21E-08	1.42E-08	1.20E-09	5.57E-08	5.99E-08	1.22E-08	3.95E-08	5.99E-08	5.99E-08	1.22E-08	3.95E-08	5.57E-08
1.33E-08	2.73E-11	6.20E-14	1.66E-11	5.96E-10	2.64E-15	2.49E-15	2.63E-33	4.28E-10	1.59E-21	3.09E-20	9.44E-14	5.95E-09	1.42E-08	6.32E-10	2.93E-08	2.25E-08	5.96E-09	· 3.95E-08	2.33E-08	2.25E-08	5.96E-09	3.95E-08	2.93E-08
PD107	SNI21M	1129	CS135	CS137	BA137M	SM148	SM151	EU152	GD152	HO166M	TL207	TL208	TL209	PB209	PB210	PB211	PB212	PB214	BI210	BI211	BI212	BI213	BI214

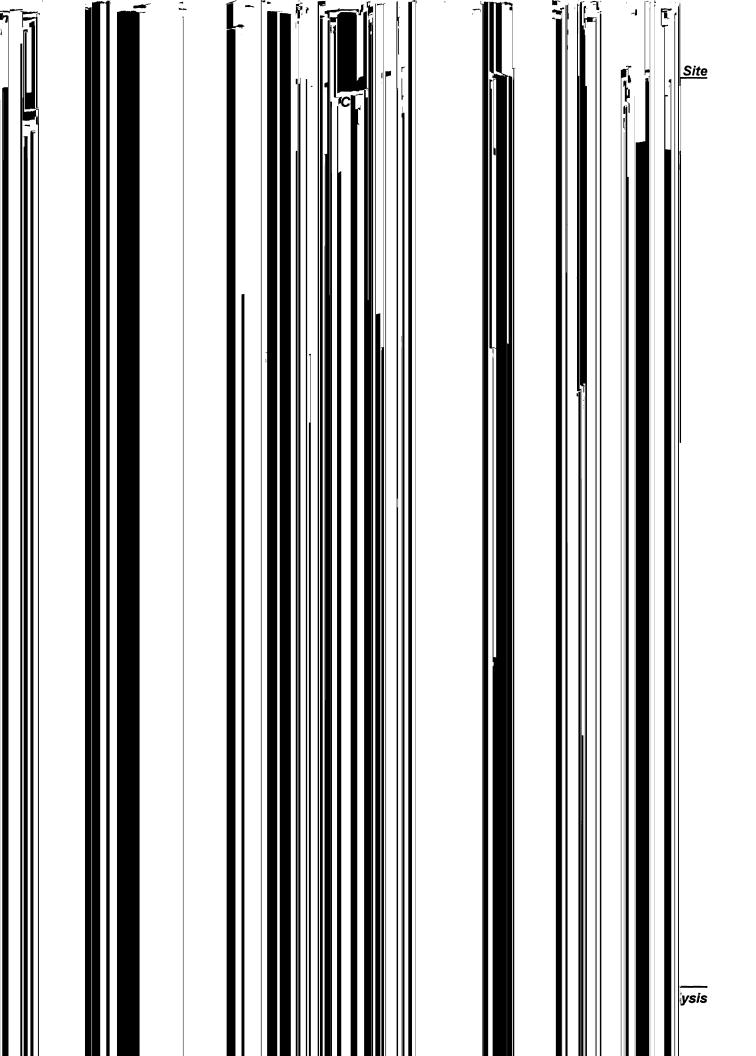
Performance Assessment/Composite Analysis

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			_	_	_	_		_			_			_		
3.95E-08	1.94E-07	6.09E-07	3.95E-08	1.94E-07	5.63E-08	3.95E-08	5.55E-08	3.95E-08	1.94E-07	7.82E-07	2.97E-07	3.95E-08	1.03E-05	5.63E-08	1.80E-08	1.03E-05
3.95E-08	1.82E-07	5.34E-07	3.95E-08	1.82E-07	5.12E-08	3.95E-08	5.05E-08	3.95E-08	1.82E-07	7.07E-07	2.97E-07	3.95E-08	1.03E-05	5.11E-08	1.80E-08	1.03E-05
3.95E-08	1.69E-07	4.59E-07	3.95E-08	1.69E-07	4.59E-08	3.95E-08	4.53E-08	3.95E-08	1.69E-07	6.31E-07	2.96E-07	3.95E-08	1.03E-05	4.59E-08	1.80E-08	1.03E-05
3.95E-08	1.55E-07	3.85E-07	3.95E-08	1.55E-07	4.06E-08	3.95E-08	4.00E-08	3.95E-08	1.55E-07	5.55E-07	2.96E-07	3.95E-08	1.03E-05	4.06E-08	1.80E-08	1.03E-05
3.95E-08	1.39E-07	3.12E-07	3.95E-08	1.39E-07	3.51E-08	3.95E-08	3.46E-08	3.95E-08	1.39E-07	4.78E-07	2.958.90	3.95H-08	1.03E-05	3.51E-08	1.80E-08	1.03E-05
3.95E-08	1.21E-07	2.40E-07	80-456E	Whitele-07	77.96E-08	3.95E-08	2.91E-08	3.95E-08	1.21E-07	4.01E-07	2.95E-07	3.95E-08	1.03E-05	2.95E-08	1.80E-08	1.03E-05
3.95E-08	1.01E-07	1.73E-07	3.95E-08	1.01E-07	2.39E-08	3.95E-08	2.35E-08	3.95E-08	1.01E-07	3.23E-07	2.95E-07	3.95E-08	1.03E-05	2.39E-08	1.80E-08	1.03E-05
3.95E-08	7.97E-08	1.12E-07	3.95E-08	7.97E-08	1.81E-08	3.95E-08	1.78E-08	3.95E-08	7.97E-08	2.44E-07	2.94E-07	3.95E-08	1.03E-05	1.81E-08	1.79E-08	1.03E-05
3.95E-08	5.57E-08	5.99E-08	3.95E-08	5.57E-08	1.22E-08	3.95E-08	1.20E-08	3.95E-08	5.57E-08	1.65E-07	2.94E-07	3.95E-08	1.03E-05	1.22E-08	1.73E-08	1.03E-05
3.95E-08	2.93E-08	2.33E-08	3.95E-08	2.93E-08	5.96E-09	3.95E-08	5.88E-09	3.95E-08	2.93E-08	8.43E-08	2.94E-07	3.95E-08	1.03E-05	6.15E-09	1.45E-08	1.03E-05
RA225	RA226	RA228	AC225	AC227	AC228	TH227	TH228	TH229	TH230	TH231	TH232	TH234	PA231	PA233	PA234M	PA234



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# Appendix 3 Conceptual Model Development Flow and Transport

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# ent - Flow and Transport

s is the development of the conceptual sses responsible for the release and transport Conceptual models developed for the Area 3 e similar to those developed for the Area 5 climatic conditions and both sites have thick the underlying aquifers. These features, the radioactive waste emplaced in shallow luvial valleys of the Nevada Test Site

hydrology at the Area 3 RWMS. The characteristics and processes typical of luxes; transforming influence of the crater and the results of the vadose zone flow and roundwater pathway is not a concern for the times of radionuclides to the water table 1 years, the length of the compliance period.

s for hydrology and transport presented in
) the period prior to formations of the
enting ambient (undisturbed) site condiemplaced in craters used as disposal units;
closure cap over the waste would be
eriod (the compliance period) during which

#### ent - Flow

ne typical of the Area 3 RWMS are depicted adisturbed conditions and conditions prior to s (m) (3 to 10 feet [ft]) of native alluvium is vary as well as the magnitude and direction apporation, and root uptake (transpiration). need by the activities of burrowing animals. apporally depending on soil properties, plant as. Below 1 to 2 m (3 to 7 ft) to a depth of vity diminish but can still occur. In the near of matric potential are superimposed on an es upward flow of water. Barometric oring about advective movement of water

vapor in pore spaces. This mechanism influences vapor flux in only the upper few meters of the alluvium. Movement of air and water over the land surface results in erosion and deposition of sediment.

#### A3.1.2 Hydrology of Crater Before Waste Emplacement

Water fluxes in the deep vadose zone are shown in Figure A3.2. The alluvium to a depth of approximately 50 m (165 ft) shows increasing total potential with depth, indicating steady upward flux of liquid water as the alluvium, distinguished by past wetter conditions, responds to the current arid climate. The thickness of this zone will vary depending on soil properties and topography. From a depth of 50 m (165 ft) to approximately 120 m (395 ft), the soil water is static. Below 120 m (395 ft), the flow is directed downward, but the magnitude is small because of the small size of the gradient. This steady downward flux is assumed to be typical of the alluvium, tuff aquifer, and tuff aquitard to the water table. The water table, at a depth of 492 m (1,614 ft), is in the tuff aquifer under the western portion of the RWMS and in the tuff aquitard under the eastern portion of the RWMS.

Craters within the Area 3 RWMS were formed by tests conducted in the early 1960s. Because some of these craters have been open for over 30 years, significant runoff has collected in them, leading to enhanced infiltration. Water fluxes in the vadose zone below a crater are depicted in Figure A3.3. Characterization studies have determined that the physical and hydraulic properties of the upper 150 m (495 ft) of the collapse zone below the crater are undifferentiated from those in the native alluvium. Comparison of properties of collapse zone and native alluvium suggests that the collapse zone is neither more nor less homogeneous than the native alluvium. The enhanced infiltration has led to the development of a zone of water content higher than background. The depth of this zone varies depending on past precipitation events and the size of the catchment area for the particular crater. For crater U-3bh, this zone extends from the bottom of the crater to a depth of approximately 80 m (265 ft) from the ground surface. The depth of wetting front movement in any individual infiltration event varies with the magnitude of the precipitation event and the magnitude and frequency of past infiltration events. Stable isotope and tritium concentration profiles suggest that there is a highly transient zone of thickness varying from 10 to 20 m (33 to 66 ft) which has experienced a relatively high frequency of infiltration events. The extent of this zone is indicated by a region of alternating depletion and enrichment of stable isotopes with depth and the depths of the tritium concentration peaks. The approximately 40 m (130 ft) below this zone is characterized by higher water content which is slowly redistributing. Within this zone, the water flux is downward, with a small outward component near the edges of the wetted region.

Stable isotope concentrations from characterization of crater U-3bh show effects of evaporation extending to as deep as 45 m (148.5 ft). This pattern is due not only to enrichment resulting from evaporation, but also to the downward movement of enriched pore water caused by intermittent infiltration events. The balance between infiltration and evaporation in this zone is important. If infiltration increases because of an increase in runoff capture following degradation of flood control structures or climate change, the depth of this zone will increase. As the depth of this zone reaches approximately 120 m (395 ft), the downward flux zone will be reached and a monotonic downward gradient will be established for flow

present, the vadose zone below 80 m he crater. Below this depth, conditions are

# owing Closure

f engineered porous materials. The shown in Figure A3.4. Assuming adequate 0 ft) of the cover will accommodate of the plant and animal activity. Plant and the bottom of the cover to a depth of adients, there will be an annual net downen upward flux of water to a depth of 5 m es in the backfill and the waste will depend le time of emplacement. Assuming that the backfill, water flux in this zone will be low the waste, water from infiltration b redistribute. With the water table 410 m ne into true equilibrium. Evaporation will potential gradients will slowly decrease n this zone is small, but mainly directed racterization results from crater U-3bh on properties of the alluvium with depth are water during redistribution.

# owing Subsidence

1 U-3ah/at have shown that subsidence will oxes (Obi et al., 1996). Potential 9 m (13 ft) in U-3ax/bl, and up to 14.9 m t the maximum potential amount of cocur sporadically, leading to localized the cap until the maximum collapse is rge uncertainty, with collapse times for the cap and waste will vary in thickness itigation practices during institutional institutional control.

omplete subsidence is shown in ssures and depressions which will tend to oisture will lead to a higher plant density. Itents lead to increased transpiration. high evaporative demand at the surface, I periods. Focusing of infiltration in the nent of wetting fronts following precipitate of anisotropy introduced with waste nce features will eventually become

e groundwater. Fissures f water vapor by

### brt

#### losure

MS varies. Waste forms il, and metal boxes ent, as well as their s occurring at the source ste packaging will not d enhance their degradaent of radion welldes in the lides will be adsorbed on

e advective and diffusive transport due to activities ocesses following waste dvection and diffusion of plant uptake, and bioturbawill be the accumulation into the atmosphere. In aur. Transport will be sion of the cover caused over by as much as 1 m ant residues off site via imated to occur at a rate

#### dence

Ibsidence are shown in
I to erosion for a surface at
or. Surface flows which
crater. The consequences
portion of the waste and
tion of fissures allows for
ed gas-phase transport due
se plant uptake and
lons will increase
water. Increased ambient
during interstorm periods.
in the surface and an

sment/Composite Analysis

#### Nevada Test Site

period following ensity of uncertainty in the aracterized by xes following les. Such an e the maximum l period, and Vadose zone g this recharge ndwater table. It ponding to a ached from the 190m [1,600 ft] of the nsport e period. Two aximized. For precipitation are iltrating into the occurs. to the undisowever, effects racks, both of thway is off from the re cap. These oisture and below the sequent advance soil column emplaced. pendix 1 an the wnward

n exposure
surface water
water. The PA
urring or have
ing water from
used the
ed playas as
t exist near the
but the water

rtly after the storms. Therefore, the playa cannot be vater. There is also no evidence that runoff has been or is ial valleys in this area.

# I Adopted for the PA/CA

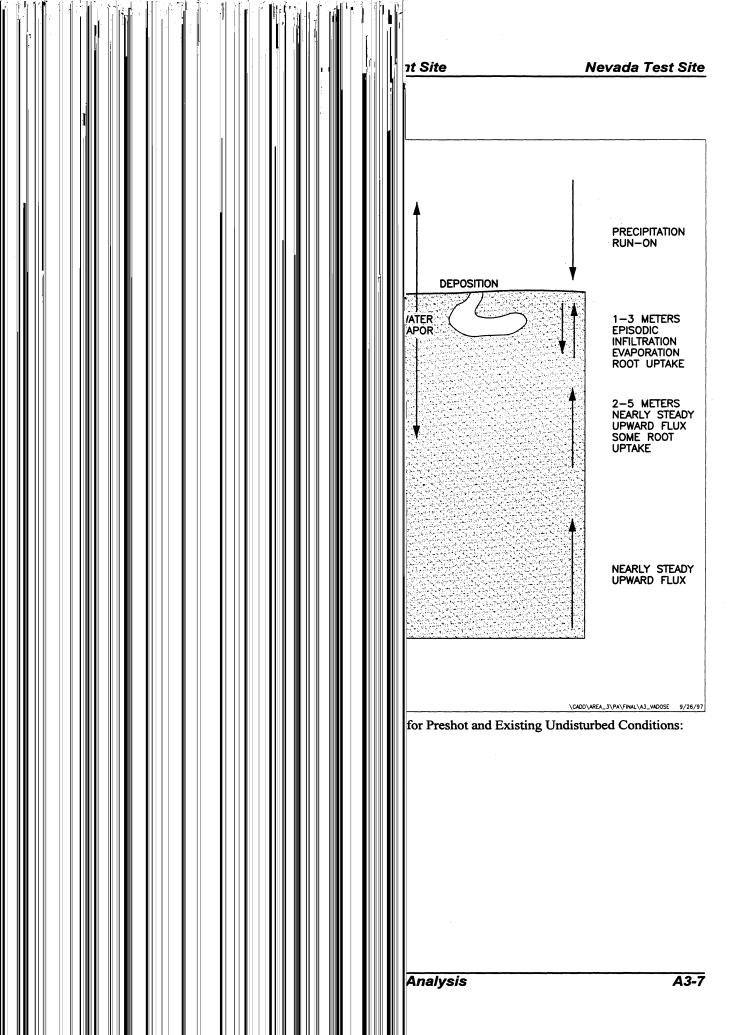
a 3 RWMS with the disposal unit subsidence, which was nd of the institutional control period, is adopted for the ual model assumes that the current climatic conditions of and low precipitation will prevail in the future. Under these cipitation infiltrating into the subsided cap returns to the

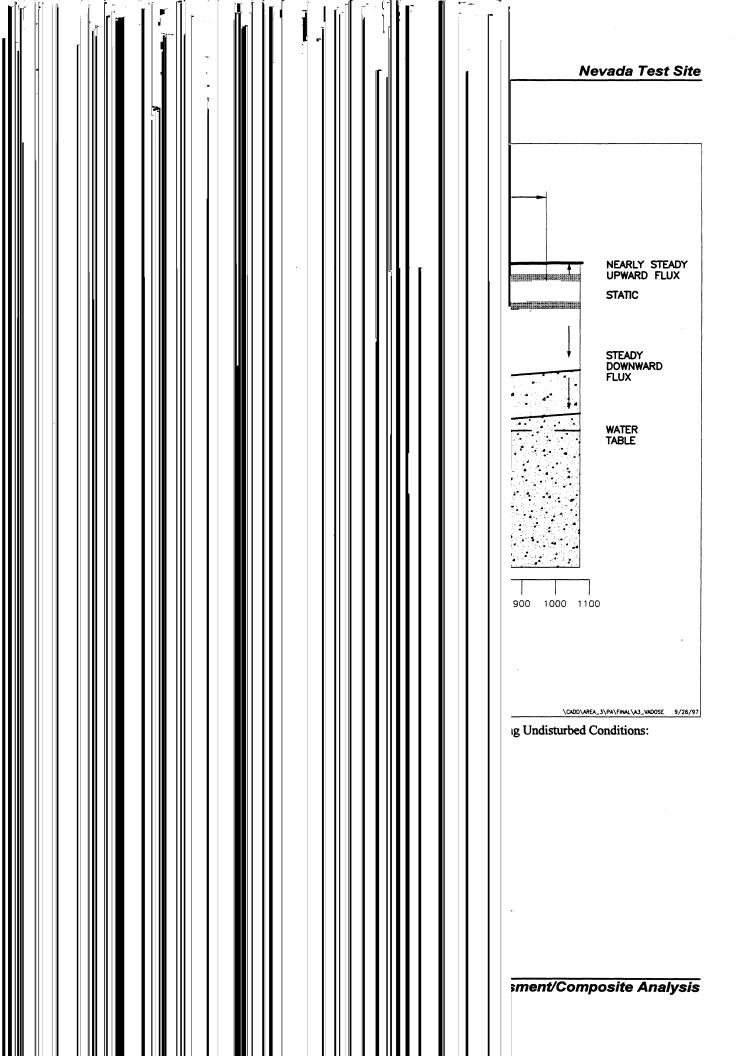
Groundwater pathway was ruled out because analyses indwater is not likely to happen in the 1,000-year complilence considered in the model are the enhancement of n and the development of cracks, both of which affect

ease and transport mechanisms were considered in the 1 Appendix 4 to implement the conceptual model. These on and diffusion of dissolved solutes, plant uptake, pension.

ick, 1995. Waste Inventory Report for the U-3ax/bl da Test Site. DOE/NV/11432-193. Reynolds Electrical & Vegas, Nevada.

Hydrogeologic Impact, and Contaminant Concentrations al Units at the Nevada Test Site." Bechtel Nevada letter of Energy, Nevada Operations Office, Las Vegas, Nevada.





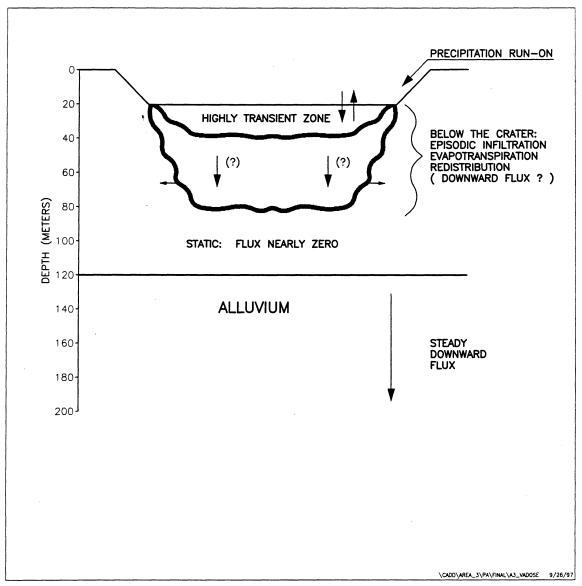


Figure A3.3 Hydrologic Conceptual Model of Crater Before Waste Emplacement

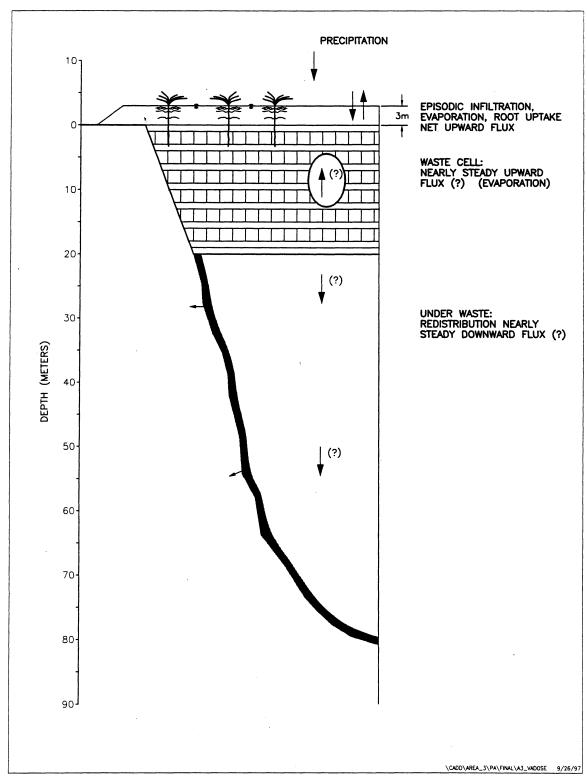
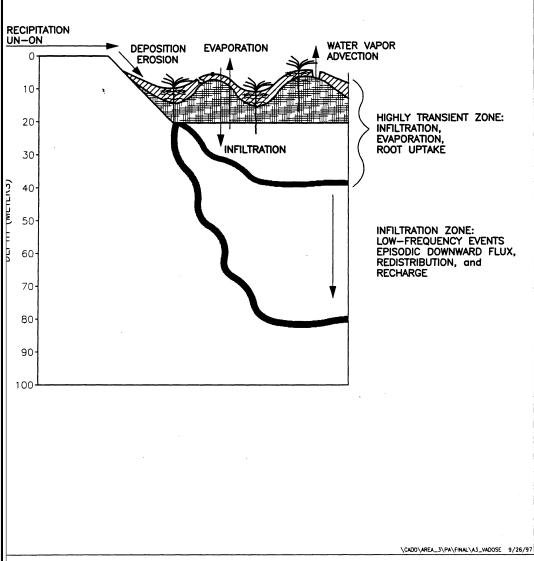
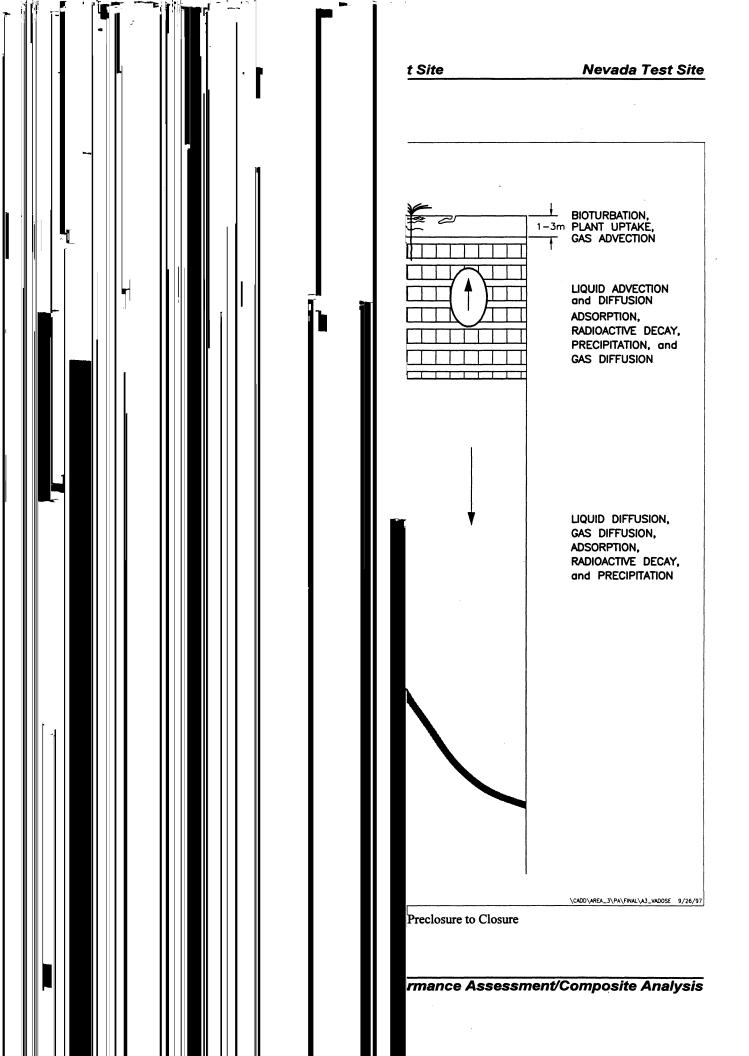
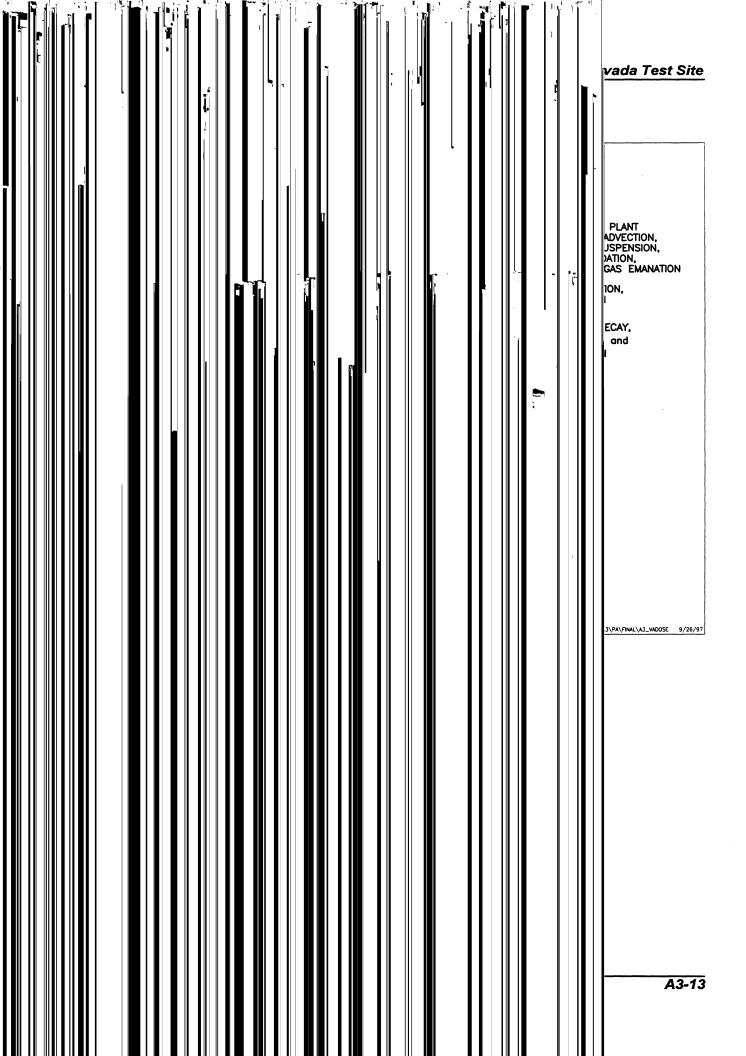


Figure A3.4 Hydrologic Conceptual Model Following Closure



3.5 Hydrologic Conceptual Model Following Complete Subsidence





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# Appendix 4 Release and Transport Models





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ase and transport assumes that the concentration of at is controlled by liquid advection, gaseous sion, and biological transport. Biological transport ion, and decomposition of native plants rooted in tried waste. Separate models are developed for the ile radionuclides, and radon.

## Radionuclides

clides is estimated using a simple and conservative mit and cap are modeled as four compartments. p compartments. The shallow waste compartment to plant roots and burrowing insects. Nonvolatile w waste compartment by plant uptake, burrowing les are released from the deep waste compartment

nents. There is a shaflow soil compartment where soil compartment, assumed to be much less aftered from the waste compartments into the cap ptake, and burrowing insects. The surface soil auclides to the atmosphere where they are advected numbering of its compartments appears in *Figure* onuclide that is a member of a nonbranching

$$A_{1,j-1} \lambda_j$$

$$\begin{pmatrix} A_{1,j} & A_{1,j} & A_{2,j-1} & \lambda_j \\ A_{23,j} + B_{23} + R_{23,j} & A_{3,j-1} & \lambda_j \\ A_{23,j} + A_{2,j} & A_{2,j-1} & \lambda_j \end{pmatrix}$$

lide j in compartment m, Ci; constant for radionuclide j, yr<sup>-1</sup>; e constant for transfer from compartment m to adionuclide j, yr<sup>-1</sup>; ate constant for transfer from compartment m to 1;

vsis A4-1

om compartment m to

ne number of atoms in any outputs. Inputs may include ant uptake, and burrowing tputs may include radioactive isport, and resuspension as into activity units by

es between the compartments the fractional loss of activity npartment. Each constant is compartment divided by the

to the compartment
ed by the transport distance
-specific, and is derived as the
ffective pore water content.

Idy-state net upward liquid liquid flux can be represented which can be estimated from estimates for water loss from 0.11 to 0.55 millimeters per in of 0.23 mm/yr (9e-3 in/yr) ration of the advective is treated as a lognormally the arithmetic space.

density (1,510 kg/m³), fic distribution coefficient, arly. The distribution and are shown in Table A4.1. compartment, and from estimated as 4.9 and gths represent average depths ll.

#### A4.1.1.2 Burrowing Animal Rate Constants

The rate of removal of activity from the shallow waste compartment by animal burrowing is assumed to be proportional to the rate of burrow excavation. The constant of proportionality is the fraction of burrow volume assumed to be in the waste. The excavated waste is assumed to be proportionally divided among the receiving soil compartments based on the thickness of each layer. The rate of removal of activity from the shallow waste compartment attributable to burrowing animal transport to shallow soils is calculated as:

$$\frac{dA_2}{dt} = \frac{C_2 M_b D_b A f_{b2}}{\rho_w} \left( \frac{x_4}{x_3 + x_4} \right)$$
 (A4.2)

and the activity in the shallow waste compartment is given by:



$$A_2 = C_2 V_2 \tag{A4.3}$$

where

 $A_2$  = activity in the shallow waste compartment, Ci;

 $C_2$  = concentration of the shallow waste compartment, Ci/m<sup>3</sup>;

 $M_b$  = burrow excavation rate, g/yr/colony;

 $D_b = \text{colony density, colony/m}$ 

 $A = disposal unit area, m^2; \quad \overline{\xi}$ 

 $f_{b2}$  = fraction of animal burrow volume in shallow waste zone,

dimensionless;

 $\rho_{\rm w}$  = waste bulk density, g/m<sup>3</sup>;

 $x_3$  = thickness of deep soil layer, m;

 $x_4$  = thickness of shallow soil layer, m; and

 $V_2$  = volume of shallow waste compartment,  $m^3$ .

Dividing Equation A4.2 with Equation A4.3 gives the burrowing animal rate constant for transfer from shallow waste to shallow soils as:

$$B_{2,4} = \frac{M_b D_b f_{b2}}{\rho_w x_2} \left( \frac{x_4}{x_3 + x_4} \right) \tag{A4.4}$$

where

 $B_{2,4}$  = the burrowing animal transfer rate constant for transfer from the

shallow waste (2) to shallow soil (4), yr<sup>-1</sup>; and,

 $x_2$  = thickness of the shallow waste compartment, m.

shallow waste to deep soils is then

(A4.5)

rate constant for transfer from the (3),  $yr^{-1}$ .

deep soil to shallow soil is given as:



rate constant for transfer from the deep; and volume in the deep soil compartment,

r rate constants are estimated using are random variables: the burrow volume in the deep soil compartment, the compartment (Table A4.2). Site-rarameter values are estimated from data ingineering Laboratory. Sufficient data ally reasonable range for each parameter. distribution of the parameters;

pth of buried waste. The shallow soil ion is expected to occur. The depth of (3 ft). Approximately 80 to 90 percent within this depth (Anderson and Allred, 9; Wallace *et al.*, 1980; McKenzie *et al.*, al transport and mixing are assumed to the compartment, 1.5 m (5 ft), assumes a

rmance Assessment/Composite Analysis

of 4.5 m (15 ft). A maximum depth of s are reported to be 2 to 3.5 m (6 to 12

removal of activity from the shallow proportional to biomass production. act of the plant-soil concentration ratio e or deep soil compartment. The eceiving soil compartments based on ach compartment. Aboveground il compartment.

partment from plants transferring



Di/g dry plant per pCi/g dry soil; production, g/m²/yr (dry); nallow waste compartment,

nallow soils compartment,

ound primary production, g/m²/yr ground.

nent from plants transferring activity

(A4.8)

py:

(A4.9)

where

 $A_3$  = activity in the deep soil compartment, Ci;

 $C_3$  = concentration in deep soil compartment, Ci/m<sup>3</sup>;

 $f_{r_3}$  = fraction of root biomass in the deep soil compartment, dimensionless;

 $\rho$  = soil bulk density, g/m<sup>3</sup>; and

 $V_3$  = volume of the deep soil compartment,  $m^3$ .

The rate of change of activity in the shallow waste compartment from plants transferring activity to the deep soil compartment is given by:

$$\frac{dA_2}{dt} = \frac{C_2 B_{j,v} B_p A f_{r2} f_{r3}}{\rho_w B_{ab}}$$



where

 $f_{r3}$  = fraction of root biomass in the deep soil compartment, dimensionless.

Dividing the activity removal rate by the compartment activity gives the rate constants as:

$$R_{2,4} = \frac{B_{j,v} B_{p} f_{r2}}{x_{2} \rho_{w}} \left( 1 + \frac{f_{r4}}{B_{ab}} \right)$$

$$R_{3,4} = \frac{B_{j,v} B_{p} f_{r2}}{x_{3} \rho_{w}} \left( 1 + \frac{f_{r4}}{B_{ab}} \right)$$

$$R_{2,3} = \frac{B_{j,v} B_{p} f_{r2} f_{r3}}{x_{2} \rho_{w} B_{ab}}$$
(A4.11)

where

 $R_{2,4}$  = root uptake rate constant for transfer from the shallow waste

compartment (2) to the shallow soil compartment (4), yr<sup>-1</sup>;

 $R_{3,4}$  = root uptake rate constant for transfer from the deep soil compartment

(3) to the shallow soil compartment (4), yr<sup>-1</sup>; and

 $R_{2,3}$  = root uptake rate constant for transfer from the shallow waste

compartment (2) to the deep soil compartment (3), yr<sup>-1</sup>.

ake rate constants are estimated using Equation A4.11. variables (Table A4.3). These are the plant-soil d primary production, and the ratio of aboveground to neters were selected to represent a subsided cap.

n ratios are geometric means derived from the ists' data set by Kennedy and Strenge (1992). The ed using the geometric mean for root, fruit, and grain data. centration ratios considering only root uptake. The plant-getables were not used because they are expected to mospheric deposition and rain splash. The data were ted based on previous reports (Ng et al., 1982; NCRP, ). Because it is unknown how well these data represent the Area 3 Radioactive Waste Management Site iation of 5.7 was selected based on the recommendations

nfiltration, which is expected to increase primary. Area 3 RWMS are analogous to subsided disposal units sites have been subsided for over 30 years and do not nasses. Therefore, relatively small increases in primary s of primary production for transitional desert and Great found. The mode was estimated as four times the S) Mojave possest communities to account for increased and Romney, 1972; Bamberg et al., 1976). The upper n value found for arid environments. The ratio of action is estimated from measurements on species ., 1995). There were insufficient data to determine the and the ratio of aboveground to belowground production.

depths at sites where subsurface water is unavailable 1995). The only source of water for plants at the Area 3 ter is 490 m (1,600 ft) below the land surface. Therefore, concentrated near the surface. The distribution of root at conservative values derived from NTS studies and and Romney, 1972; Wallace et al., 1980; Foxx et al., lata support the assumption that 4.5 m (15 ft) is a fost data suggest that very little root biomass is present at vallace et al., 1980; Kennedy et al., 1985).

allow soil compartment are lost by resuspension and tes have been estimated for nuclear weapons testing sites inn and Homan, 1985; Shinn *et al.*, 1986). These authors' ated by dividing the measured Pu aerosol flux by the Pu

alculated assuming a 5-centimeters ation layer (Shinn and Homan, 1985; the nonvolatile radionuclide release ate for the different depth distributions, g a 1-m- (3-ft)-thick uniformly ctor of 20 reduction in the resuspension selected, as these most conservatively om the disposal sites. At the nuclear ss particulates that are not readily suspension rates on the NTS at 6 to 6e-4 yr<sup>-1</sup> (Anspaugh *et al.*, 1975; es is estimated to be 2e-5 yr<sup>-1</sup>. The soil stribution with a mode of 2e-5 yr<sup>-1</sup> and

set of differential equations described tions. The code includes an algorithm fferential equations, and random is. The radioactive decay chains were y with half-lives less than one year are. Mass balance expressions were ne code converts the radionuclide al effective dose equivalent (TEDE) ribed in Appendix 7. The SDCFs give it plus the dose from any progeny

indom number generator; number of neir types such as normal, lognormal, te Carlo simulations to be performed; lation; surface area of the disposal unit; ne bulk densities for soil and waste; the ecay rates and distribution coefficients the chains in the waste compartments; pension rate, plant uptake parameters, the and media specific SDCFs for the

primary productivity, the ratio of nventory are treated as random mate of the waste inventory and its bry is assumed to have a triangular to estimate the advective transport rate to estimate rate constants for

3, respectively. The parameters are provided in

, and U-3bh disposal units. realizations. The output of Carlo realization, the time-1,000 years) for each e scenario at selected time

bus diffusion through the air surface is estimated from btained from an analytical g gaseous diffusion and the gases within the cap. Eve parent diffusing

(A4.12)

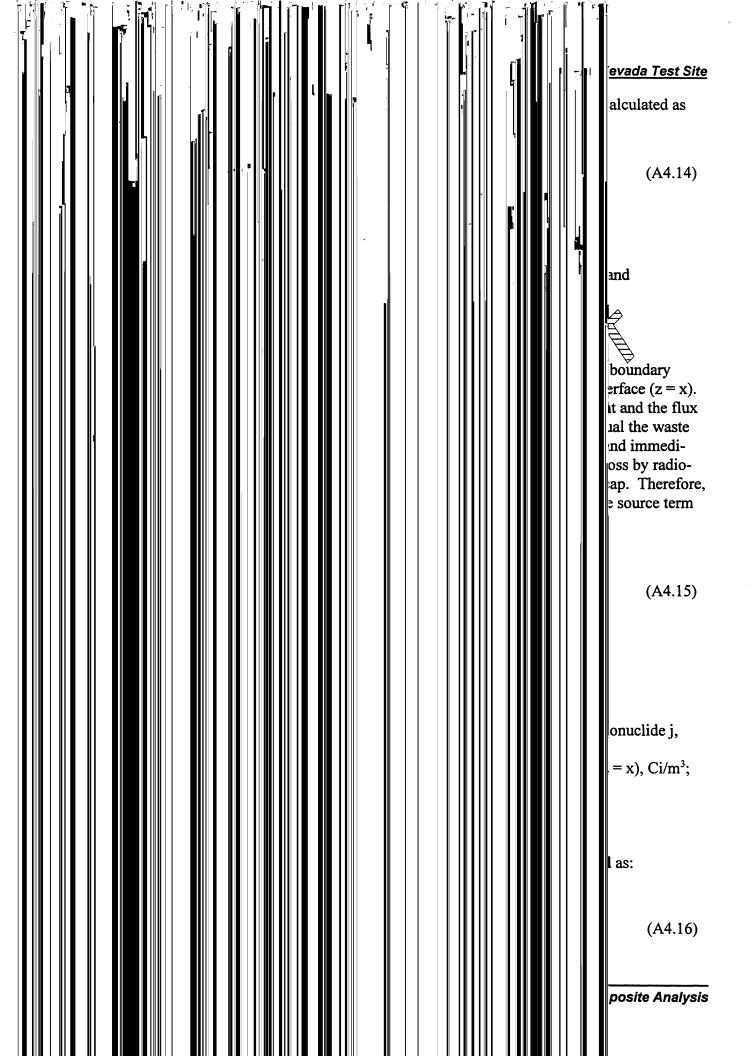
le j, Ci/m³; uclide j in the porous

i, yr<sup>-1</sup>.

i) as:

(A4.13)

r unit area of the bulk



subside at closure, causing cracking of the cap. Cracks are assumed to ways for gas release. The concentration profile in a crack is assumed 1 (A4.16), assuming the diffusion coefficient is equivalent to the free... The flux density from cracks is given by:

$$= -D_{a,j} \frac{\partial C_{g,j}(z,t)}{\partial z}$$
 (A4.17)

the flux density of radionuclide j per unit area of cracks, Ci/m²/s.

of the cap area is open cracks,  $f_c$ , the mean flux density at the cap-air a by:

$$e^{-\lambda_{j}t} \left[ f_{c} \sqrt{\lambda_{j} D_{a,j}} \operatorname{csch} \left( x \sqrt{\frac{\lambda_{j}}{D_{a,j}}} \right) \right]$$

$$\varepsilon \sqrt{\lambda_{j} D_{e,j}} \operatorname{csch} \left( x \sqrt{\frac{\lambda_{j}}{D_{e,j}}} \right) \right]$$
(A4.18)



the mean flux density at the cap-air interface of radionuclide j per unit area of the bulk medium, Ci/m²/s; and the fraction of the cap area as open cracks, dimensionless.

e present predominantly as tritiated water (HTO). Therefore, there is be released by plant transpiration. The plant transpiration loss is the flux density from the bare waste. The flux density of <sup>3</sup>H is given

$$(x,t) = C_{g,H3}(0,0) e^{-\lambda_{H3}t} \left[ f_c \sqrt{\lambda_{H3}D_{H3}} \operatorname{csch} \left( x \sqrt{\frac{\lambda_{H3}}{D_{H3}}} \right) \right]$$

$$\sqrt{\lambda_{H3}D_{e,H3}} \operatorname{csch} \left( x \sqrt{\frac{\lambda_{H3}}{D_{e,H3}}} \right) + \varepsilon_w \sqrt{\lambda_{H3}D_{e,H3}} \operatorname{coth} \left( x \sqrt{\frac{\lambda_{H3}}{D_{e,H3}}} \right) \right]$$
(A4.19)

= waste porosity,  $m^3/m^3$ .

balance constraint, it is assumed that the flux density, integrated over one year and I site area, cannot exceed the total waste inventory. Therefore, an upper limit on state flux density is set as:

$$J_{j,\max}(x,t) = \frac{C_{w,j}(0) x_w e^{-\lambda_j t}}{\Delta t}$$
(A4.20)



max(x, t) = upper limit of gaseous flux density for radionuclide j per unit area of the bulk medium, Ci/m<sup>2</sup>/yr;

 $w_{i,j}(0)$  = waste concentration at closure for radionuclide j, Ci/m<sup>3</sup>;

= unsubsided waste cell thickness, m;

= time elapsed since closure, yrs; and

= regulatory interval, 1 yr.

concentration in the waste pore gas is calculated assuming the entire inventory is the gas-filled pore spaces. For all nuclides other than <sup>3</sup>H, the pore gas on is given by:

$$C_{g,j}(0,0) = \frac{C_{w,j}(0)}{\varepsilon - \theta_v}$$
(A4.21)

 $C_{w,j}(0) =$  waste concentration of radionuclide j at closure, Ci/m³; and  $\theta_v =$  volumetric water content, m³/m³.

H pore gas concentration is calculated assuming that the specific activity of <sup>3</sup>H in waste water is equal to the specific activity of vapor in the waste air-filled pore space. The entration of the waste pore gas is given by:

$$C_{g,H3}(0,0) = 10^3 \frac{C_{w,j}(0) P_v MW}{\theta_v RT \rho_{H_2O}}$$



 $10^3$  = unit conversion factor, 1e3 L/m<sup>3</sup>;

 $P_v = \text{vapor pressure of water, 1.2e-2 atmospheres (atm);}$ 

MW = molecular weight of water, 18 g/mole;

R = gas constant (0.082 liter-atmospheres per mole-degree Kelvin [L

atm/mole K]);

T = temperature (283 K); and

 $\rho_{\rm H2O}$  = density of water, 1e6 g/m $_{\Xi}$ 

concentration of gaseous radionuclides at the 100-m (330-ft) site boundary was estimated





 $C_{a100, j}(t)$  = the atmospheric concentration of radionuclide j at the 100-m

boundary at time t, Ci/m<sup>3</sup>;

A = area of the disposal unit,  $m^2$ ; and

X/Q = the mean annual ratio of ground level atmospheric

concentration to release rate at 100 m, s/m<sup>3</sup>.

The annual mean X/Q factor was estimated using the EPA CAPP88-PC (Ver. 1.0) computer code (EPA, 1992). This is a Gaussian plume atmospheric dispersion model. The atmospheric concentration at 100 m (330 ft) was used to estimate the TEDE for the community scenarios and for the CA.

The atmospheric concentration directly over the cap was estimated assuming steady-state mixing of the flux into a compartment. Assuming steady-state mixing into a zone above the waste disposal site, the concentration of a gaseous radionuclide is given by:

$$C_{a,j}(t) = \frac{J_j(x,t)\sqrt{A}}{HU}$$
(A4.24)

where

 $C_{a,i}(t)$ the atmospheric concentration of gaseous radionuclide j over the cap at time t, Ci/m<sup>3</sup>;

height of the mixing zone, m; and annual mean wind speed, m/s.

The atmospheric concentration over the cap is used to estimate the TEDE to intruders.

Parameter Selection. Seven parameters in the gas release model are evaluated as random variables (Table A4.4). They are porosity; area of the cap as cracks; the waste concentration of <sup>3</sup>H, <sup>14</sup>C, <sup>39</sup>Ar, and <sup>85</sup>Kr; and the wind speed in intruder scenarios; or X/Q in scenarios for the member of public. The only parameter assumed to be affected by subsidence was the water content and the formation of cracks. Higher water contents are assumed to reflect increased infiltration into a subsided cap.

The porosity data are total porosities for samples collected at boreholes at the Area 3 RWMS (Bechtel Nevada, 1996a,b; 1997). The square of porosity was found to be normally distributed (Anderson-Darling Statistic, p-value ≈ 0.4). Porosity is calculated as the square root of the transformed random variable. The effect of cap water content on porosity was ignored. Water will reduce the effective porosity and reduce the diffusive flux.

A conservative conceptual model of crack formation was assumed to be that 2-cm (0.8-in) cracks formed every 30 cm (12 in) over the cap. This corresponds to a total area for open cracks equal to approximately 10 percent of the cap. Crack area was assumed to vary uniformly from 0 to 10 percent.

The waste concentrations are assumed to be triangularly distributed with a mode equal to the inventory best estimate (see Appendix 2). The concentrations are assumed to range from 0.1 to 10 times the best estimate. The waste concentrations are assumed to be correlated with a

#### Nevada Test Site

tive as they

onal Weather for 1983 through mally distributed.

eteorological data ucca Flat station.
Calculations were
) was 9.1e-5 s/m³
bared the results
PARISH 1992; NCRP,
s within a range
from 2e-5 to 3e-4
s/m³.

olumetric water ers in the Area 3 echtel Nevada, ), is the area the disposal unit n (21 ft) using a t was assumed to

h an Excel<sup>c</sup>
Ball (Ver. 4.0)
rith 1,000 Monte

(NRC) Regulatory nterface is calcumby radioactive density is neem because of 1 by a 220 Rn atom ly 1 cm (0.4 in) even less. attenuate the flux

$$D_{e,Rn} \varepsilon \frac{\partial C_{Rn}}{\partial z}$$
 (A4.25)

adon flux density per unit area of the bulk medium, pCi/m²/s; tive diffusion coefficient for radon, m²/s; sity, m³/m³; and

n concentration in the gas-filled pore spaces, pCi/m<sup>3</sup> \( \triangle \)

ith depth is obtained as the solution to a one-dimensional idering gaseous diffusion, radioactive decay, and production by ation of continuity is written as (NRC, 1989):

$$\frac{(z,t)}{2} - \lambda_{Rn} C_{Rn}(z,t) + \frac{R \rho E \lambda_{Rn}}{\varepsilon}$$
(A4.26)

n radioactive decay constant, s<sup>-1</sup>; entration of <sup>226</sup>Ra in the solid matrix, pCi/g; density, g/cm<sup>3</sup>; and atton coefficient, dimensionless.

ficient for radon is calculated using the empirical relationship of as:

$$\left| \epsilon e^{\left(-6 S \epsilon - 6 S^{14 \epsilon}\right)} \right|$$
 (A4.27)

diffusion coefficient in free air, m<sup>2</sup>/s; and he fraction of water saturation, dimensionless.

ed version of the empirical relationship recommended in NRC he effective diffusion coefficient (Rogers and Nielson, 1991).

Analytical solutions for the flux density equation and equation of continuity are available for a two-layer problem if several assumptions are made. The solution assumes steady-state conditions. Additional assumptions are that concentration and flux are continuous at the waste-cap boundary, that concentration is zero at the air-cap boundary, that radon in the air-filled pore space is in equilibrium with radon in the water-filled pore space, and that radon production is negligible in the cap. There is the potential for radium from the waste to accumulate in cap soil by the mechanisms described in Section A4.1. However, it can be shown that the radon flux density from radium in the cap is small compared to the flux density from the waste. Therefore, this source of radon flux density can be ignored. With these assumptions, it can be shown that the flux density is given by (NRC, 1989):

$$J_{Rn} = \frac{2 R_w \rho_w E_w \sqrt{\lambda_{Rn} D_{e,Rn,w}} \tanh \left( x_w \sqrt{\frac{\lambda_{Rn}}{D_{e,Rn,w}}} \right) e^{-x_c \sqrt{\frac{\lambda_{Rn}}{D_{e,Rn,c}}}}}{1 + \sqrt{\frac{a_w}{a_c}} \tanh \left( x_w \sqrt{\frac{\lambda_{Rn}}{D_{e,Rn,w}}} \right) + \left[ 1 - \sqrt{\frac{a_w}{a_c}} \tanh \left( x_w \sqrt{\frac{\lambda_{Rn}}{D_{e,Rn,c}}} \right) \right] e^{-2x_c \sqrt{\frac{\lambda_{Rn}}{D_{e,Rn,c}}}}}$$

where

 $\begin{array}{lll} R_w & = & \text{concentration of } & \text{Ra in waste, pCi/g;} \\ \rho_w & = & \text{bulk density of waste, g/cm}^3; \\ E_w & = & \text{emanation coefficient of waste, dimensionless;} \\ D_{e,\,Rn,\,w} & = & \text{effective diffusion coefficient for radon in waste, m}^2/s;} \\ D_{e,\,Rn,\,c} & = & \text{effective diffusion coefficient for radon in cap, m}^2/s;} \\ x_w & = & \text{thickness of waste, m; and} \\ x_c & = & \text{thickness of cap, m.} \\ \end{array}$ 

The calculated parameters a<sub>w</sub> and a<sub>c</sub> are given by:

$$a_{w} = \varepsilon_{w}^{2} D_{e,Rn,w} \left[ 1 - (1 - k) \frac{\theta_{w}}{\varepsilon_{w}} \right]^{2}$$
(A4.29)

and

$$a_c = \varepsilon_c^2 D_{e,Rn,c} \left[ 1 - (1 - k) \frac{\theta_c}{\varepsilon_c} \right]^2$$
 (A4.30)

ity, m³/m³; ibution coefficient for radon in water, pCi/cm³ water content of waste, cm³/cm³; , m³/m³; and content of cap, cm³/cm³.

sidence. Radon flux density in cracks is calculated as fficient. The total radon flux density was calculated

s in the radon flux density calculation are treated as rameters are waste bulk density, waste emanation, waste volumetric water content, cap volumetric acks, and waste <sup>226</sup>Ra concentration.

v uniformly over a range of observed values for nt was assumed to vary uniformly from a lower limit imum of 1.0. Waste porosity was assumed to vary we of alluvium and a physically reasonable upper limit ic water content were modeled as described in the aste and cap volumetric water content are assumed of alluvium beneath a subsided crater is assumed. The led as described in the volatile radionuclide release tration was assumed to range from 0.1 to 10 times the he distribution was assumed to be triangular.

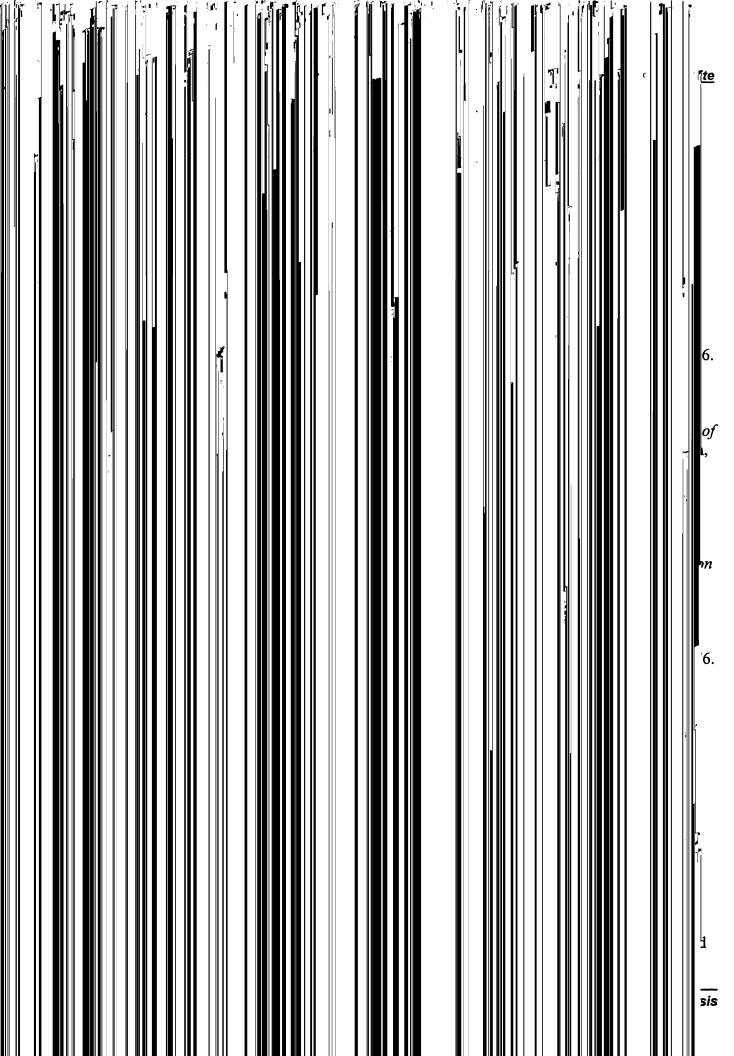
A4.7. The radon diffusion coefficient in free air is lling between 1.0e-5 and 1.2e-5 m<sup>2</sup>/s (van der Spoel <sup>2</sup>/s was selected (Rogers and Nielsen, 1991).

x density model was implemented with an Excel<sup>o</sup> were implemented with the Crystal Ball (Ver. 4.0) bilistic simulations were prepared with 10,000 Monte

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4. "Kangaroo Rat Burrows at the Nevada Test Site." 11.

## Nevada Test Site uspension and . "A Comparison Vet and Dry n Southern Zone: Data la Qperations August 1996. s Vegas, Nevada. November 1996. s Vegas, Nevada. e Seedin Seven Plant tho Acad. Science sal Site Based on nt Division, U.S. C. Weast and efficient of lealth Physics 30: ring, Inc., 988-PC, Version of Radiation terization of the PNL-2774.



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Table A4.1 Geometric Mean Distribution Coefficients for Sandy Soil Type (from Yu et al., 1993)

Element	Distribution Coefficient (m³/kg)	Element	Distribution Coefficient (m³/kg)
Н	0	Cs	0.28
С	0.005	Sm	0.245
Cl	, 0.0017 <sup>†</sup>	Eu	0.24†
K	0.015	Gd	0.24†
Ca	0.005	Но	0.25 <sup>†</sup>
Co	0.06	Pb	<u>Ø</u> 27
Ni	0.4	Ra	0.5
Sr	0.015	Ac	0.45
Zr	0.6	Th	3.2
Nb	0.16	Pa 🖨	Ø 0.55
Тс	0.0001	n	0.035
Pd	0.055	Np	0.005
Cd	0.08	∼ Pu	0.55
Sn	0.13	Am	1.9
I	0.001	Cm	4

<sup>† -</sup> from Kennedy and Strenge (1992)





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#### Used to Estimate Plant Uptake Rate Constants

	Value (Source)
lant y soil	Lognormal, Arithmetic Mean: 3.2, Stand. Dev.: 14 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 3.2e2, Stand. Dev.: 1.4e3 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 2.5, Stand. Dev.: 11 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 1.6, Stand. Dev. 1 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 1.2, Stand. Dev.: 5.3 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 0.022, Stand. Dev.: 0.10 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 4.8, Stand. Dev.: 21 (Sheppard and Evendon, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 0.027, Stand. Dev.: 0.12 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 0.30, Stand. Dev.: 1.3 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
lant y soil	Lognormal, Arithmetic Mean: 0.023, Stand. Dev.: 0.10 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
olant y soil	Lognormal, Arithmetic Mean: 0.013, Stand. Dev.: 0.058 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
olant y soil	Lognormal, Arithmetic Mean: 0.0016, Stand. Dev.: 0.0071 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)
olant y soil	Lognormal, Arithmetic Mean: 0.0011, Stand. Dev.: 0.0050 (Sheppard and Evenden, 1997; Kennedy and Strenge, 1992)

## evada Test Site e-2, Mode: ie-1, Mode: .6e-4 e-7, Mode: je-6, Mode: Mode: 1.2ee-7, Mode: ie-6, Mode: 7, Mode: 1.3e-·e-5, Mode: ie-4, Mode: 5, Mode: 1.7ela, 1996a,b; v.: 0.17 e: 9.1e-5 0.019, (Max.)<sup>2</sup>: A4-27

Table A4.5 Fixed Parameter Values for the Gaseous Radionuclide Release Model

		Vi	alue						
Parameter	3H	14C	<sup>39</sup> Ar	**K	Source				
$\lambda_{j,k} (yr^{-1})$	0.0564	1.21e-4	2.58e-3	0.0646	Kocher (1981)				
$D_{a,j,k} (m^2/yr)$	754	440	630	280	CRC (1981); Am. Inst. of Physics (1972)				
$D_{e, j, k} (m^2/yr)$	498	290	416	185	After Culot (1976)				
Cap Thickness, x (m)			3		Assumed Final Cap Thickness				
Waste Thickness, x <sub>w</sub> (m)		7	<i>1.</i> 7		U-3ah/at Area-Weightert Mean Waste Thickness				
Waste Thickness, x <sub>w</sub> (m)		6	5.4		U-3ax/bl Area-Weighted Mean Waste Thickness				
Waste Thickness, x <sub>w</sub> (m)		6	5.8		U-3bh Area-Weighted Mean Waste Thickness				
Cap Area, A (m²)		34	,820		Estimated U-3ah/at Surface Area				
Cap Area, A (m <sup>2</sup> )		35	,977		Estimated U-3ax/bl Surface Area				
Cap Area, A (m <sup>2</sup> )		19	,000		Estimated U-3bh Surface Area				
Cap Mixing Cell Height, H (m)			2		Minimum Height Occupied				

Table A4.6 Parameter Values for Random Variables in the Radon Flux Density Model

	$\mathcal{A}\mathcal{A}$	
Parameter	Units	Distribution (Source)
Cap Porosity, $\varepsilon_c$	m³/m³	Normal, (Mean) <sup>2</sup> : 0.141, s <sup>2</sup> : 0.046, (Min.) <sup>2</sup> : 0.019, (Max.) <sup>2</sup> : 0.30 (Bechtel Nevada, 1996a,b; 1997a)
Waste Porosity, Ew	$m^3/m^3$	Uniform, Min.: 0.37, Max.: 0.67
Waste Bulk Density ow	g/cm <sup>3</sup>	Uniform, Min.: 0.28, Max.: 1.50
Waste Emanation Coefficient, E	dimensionles s	Uniform, Min.: 0.05, Max.: 1.00 (Nazaroff, 1992)
Volumetric Water Content, $\theta_{\rm v}$	m³/m³	Normal, Mean: 0.15, s: 0.03 (Bechtel Nevada, 1996a,b; 1997a)

#### Distribution (Source)

U-3ah/at: Triangular, Min.: 6.9e-9, Max.: 6.9e-7, Mode: 6.9e-8 (Appendix 2)

U-3bh: Triangular, Min.: 2.9e-9, Max.: 2.9e-7, Mode: 2.9e-8

(Appendix 2)

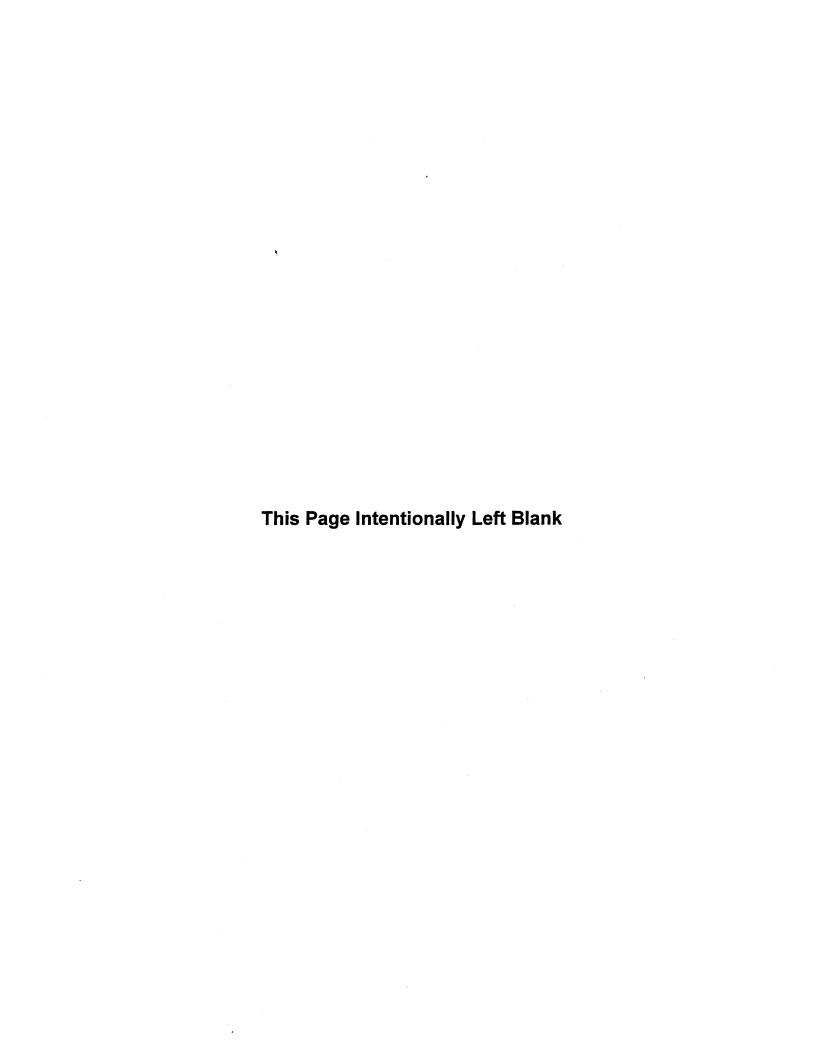
Uniform, Min.: 0, Max.: 0.10 nless

#### r the Radon Flux Density Model



Value	Source
1.1e-5 m <sup>2</sup> /s	Rogers and Nielson (1991)
7.7 m	Area Weighted Waste Depth for U-3ah/at
6.8 m	Area Weighted Waste Depth for U-3bh
3.0 m	Assumed U-3ah/at Cap Thickness
I ←	









### Appendix 5

# Probability of Inadvertent Human Intrusion in the Area 3 RWMS





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ed experts (Casti, 1990; Meyer and

Flat, via the mechanism of water well d approved by a panel of experts. The were used as model inputs. Assembling volved the following steps:

on models were developed by the com DOE/Nevada Operations National Laboratories. These tensive internal and external review,

nodels were presented to various I acceptability (Mathai et al., 1996). en Alert, the Community Advisory Program, the Nevada Department of lear Waste Project Office, and the rios and models were modified to

is) was assembled. These SMEs ithropology, demography, 1g, hydrogeology, hydrology, land SMEs were selected in a manner ional bias (e.g., no connection with radioactive waste; no current re trained in expressing beliefs as ios and models, SMEs expressed puts. These input probability s of the probability of IHI.

ted follows. Complete details appear in

arios were found sufficiently credible to h isolated individuals (discussed in Section on A.5.1.2).

lative isolation, in Yucca Flat. Such a ome does not depend on location (e.g., of ranching, mining, or raising cash crops,

SMEs as very unlikely because of the considerable mate. However, the exposure scenario assumes that le garden and mix contaminated drill cuttings with the n occur. This scenario was distinguished from nity scenarios" is defined below, by assuming relative f shared resources between homesteads.

as opposed to isolated individuals or families, are "scenarios. Three community scenarios were ons A5.1.2.1 through A5.1.2.3.

#### nario

of a community in Yucca Flat. Here, the word le prisons, military bases, research facilities, and cities. This scenario is distinguished from the lat: community members share resources, an exists for a community water supply adequate to

#### Scenario

rio, Las Vegas grows large enough to exert population

he city limits, but who share resources with the city icca Flat. Under the assumption that Las Vegas ected to occupy Yucca Flat prior to a community

like the Homestead scenario, individuals living in is Vegas scenario differs from the Homestead scenario icca Flat have the option to share resources with a iffectively, a hybrid of the Homestead and Base

#### io

ommunity, where "community" is used as above, that some other location near Yucca Flat. In this scenario, o, some individuals who prefer living outside the arces with the community, settle in Yucca Flat. The cass Flats. Jackass Flats, although judged by the SMEs nmunity to arise on what is now the Nevada Test Site cation near Yucca Flat where a community might and Mountain, west of Jackass Flats, is the potential radioactive waste repository and that Jackass Flats has

Analysis A5-3

storage. Because of the uncertainty in litions continue. This assumption might as a repository or interim storage facility.

y of IHI in terms of several variables was es; for others, SMEs assigned probability These models, discussed below, prod on the ineffectiveness of management the length of time institutional control of IHI was calculated by multiplying the compliance period during which controls is follows the descriptions of the scenario

#### s Depicting the Homestead

f IHI via the homestead scenario depends

in Yucca Flat at a given point

restead remains viable).

ins viable).

urring in the next n years

rage).

rs in Figure A5.1. Influence diagrams, cy analysis, represent a model's essential numbers or mathematical formulae. The sussed in the following paragraph. The e influence diagram itself.

robabilities were directly elicited from fit to the SMEs' input. Monte Carlo rom each cdf. These were combined, as

ormance Assessment/Composite Analysis

#### Nevada Test Site

itional scenario nal scenario ction of those the 10,000

nodes 1, 2, and 3 homestead e., a fixed utions, from the describe the

):

gnore

thin the ce between in the istributions for ation for node 4

pended on of homesteaders' ne factors in e 7 depended on

unity Scenarios ditional veral variables. el; these were

nario model. Models and influence diagrams n detail here; influence diagrams and detailed ).

IHI depended on:

ccurring in the next n years increases

verage).

ts, rather than being elicited from the SMEs.

he base community scenario and whose

iber of communities present in Yucca

community remains viable).

ars a given community well remains

lacement wells within a community.

Flat was occupied by commuting icited for:

which could cause commuter at exist in Jackass Flats.

ommunity.

on Yucca Flat. Probability distributions

Performance Assessment/Composite Analysis

opulation

via that scenario was rint, size of Yucca Flat or each community I realizations of each Es. All realizations Using these realizations is tribution function ibution of the prio, the mean of the enario, the unconditional the conditional riod that management

e factors, as defined d markers, surface

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prohibits public
Es considered and
SMEs held that
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d access of the NTS, periodic patrols of

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nal control, as modified by SME and

ontrol cannot be maintained into the torical scarcity of human institutions opinion of the SMEs, institutional ag societal priorities rather than through the time during which institutional

st within 50 years = 0.1

st within 500 years = 0

st within 1,000 years = 0.9

lognormal distribution with a geometric standard deviation of 2.66 (unitless), I opinion for other values. The value of

,000 realizations of the effectiveness of sted from SME input pertaining to the asion based on cdfs for the institutional s for the remaining management ations for the management controls nal scenario probabilities resulted in a probability of IHI. The mean value of pability of IHI. The probability of IHI olying the contents of node 10 in the lon failure of management controls) by portion of the compliance period that

#### h Intrusion

lity of the Jackass Flats scenario mmunity scenarios by at least two ability of the Jackass Flats scenario d scenario by multiple orders of scenario were ignored in calculations mpact.

for a 10,000-year compliance period and or a 1,000-year compliance period and

#### vada Test Site

ingly, the ed as 0.0063. Fraction of le (most 0 years. 1,000-year mpliance 1.75 = 0.0047.

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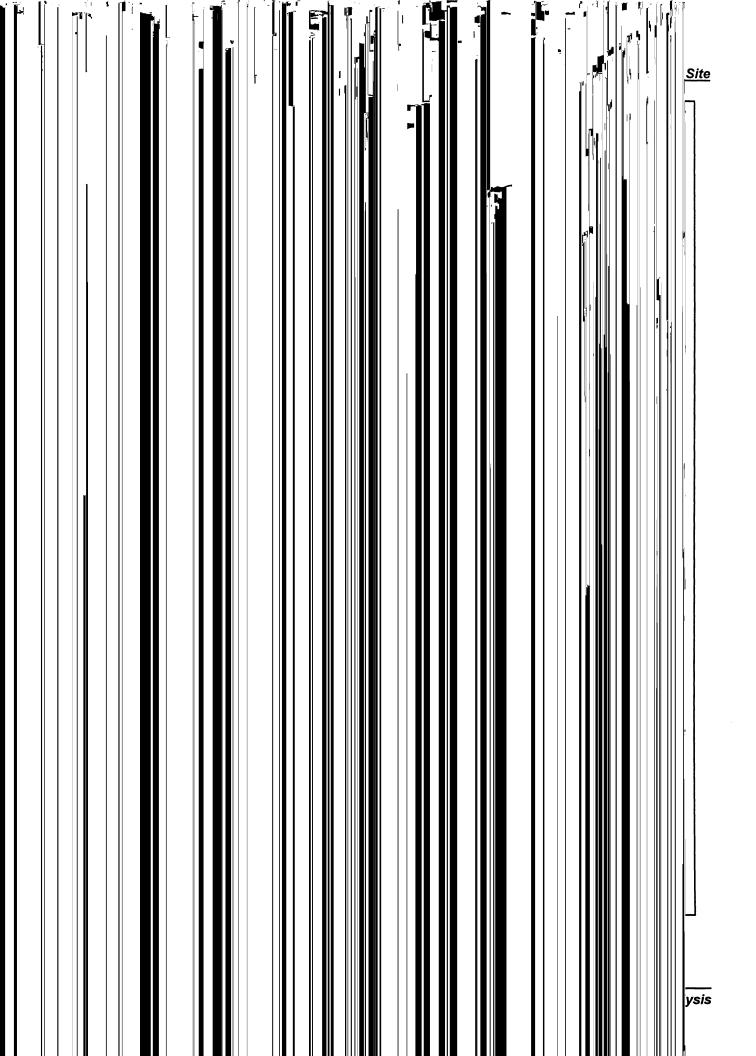
Introductory Lectures on Choices Under Uncertainty. o.

DE Order 5820.2A, Radioactive Waste Management. Vashington, DC.









### **Appendix 6**

**Composite Analysis and Air Transport Modeling** 

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tions in five locations on the NTS (Yucca Flat, Flat, and Jackass Flats) could potentially interact S. The CA is limited to sources within Yucca Flat eatest in Yucca Flat, due to both the location of the 7e use for nuclear testing. Plutonium Valley, a small cluded in the analysis.

radiation which exist within Yucca Flat are numerous sites of nuclear tests, both atmospheric

#### ental Pathways



is released from multiple source areas to receptor econdary source for radionuclides to be transported ation or seepage. Contaminated soils (and possibly nsidered here) are the only sources with the potential

ne existence of perennial surface water features.
nedium for multiple source term interaction exists.
produce alluvial fan flooding, with water accumury lakes or playas is evidence of past accumulation of
the valleys. However, surface evaporation and
nding on the playa from occasional flooding is, at
water pathway is not a significant exposure pathway

#### ıway

nsport occurring during floods can cause interaction areas. Flood waters can transport eroded soils leposit these soils in playas, such as Yucca Flat

noff. Because most source inventory is associated associated radionuclides transported towards Yucca in small erosion rates, no significant runoff-induced it areas is expected within the 1,000-year compliance transport are not considered credible pathways.

dwaters beneath Yucca Flat are the contaminated 1 the Area 3 RWMS disposal cells.

of the Ash Meadows Groundwater Basin, the NTS and adjacent areas to the east son, 1975). Four primary lithologies the NTS: valley-fill alluvium, tuff, ed tuffs and carbonates form aquifers, litards.

ed zone separates the surface sources of Yucca Flat. The depth to the water table Most underground tests were performed ames of radionuclides in groundwater underground tests performed below the

primed for the Performance Assessment flow modeling shows that under a liated ponding event in the subsided be 1,200 years after facility closure. For cess of 10,000 years (see Appendix 1). pathway.

lley, sources considered for atmospheric Plutonium Valley sources are included on rates, and proximity to the Area 3

transport of radionuclides from Plutonium of contaminated soils from Yucca Flat rs to air flow within Yucca Flat. ces in or near Yucca Flat have the LWMS.

e CA for the 1,000-year compliance or locations are determined at different bils source areas. Two U.S. Environidely used in the industry are evaluated. kage 1988 (CAP88-PC) (EPA, 1992) and del (EPA, 1995). CAP88 is an approved of Federal Regulations (CFR) 61, es to DOE facilities that emit radionuzardous waste facilities with air emissions

AP88 can provide estimates of receptor odels can only provide estimates of receptor adionuclides at a single source, while ISC le radionuclide. Because dose assessments for hods, only the ability to provide exposure the area sources of the ISC models is found ceptors are located very near to or within the models to treat multiple sources is an added were chosen to perform the air transport

erm (ISCST) or the Long-Term (ISCLT) prological data for modeling emissions and t at a typical industrial complex. The sources purces, and open pit sources. While ISCST is ISCLT is used for seasonal or annual long-term equencies of occurrence for particular wind pility categories as meteorological input. This summary.

ng the average annual STAR summary data at odel description, the parameters selected for the It is noted that because the ISC set of models is missions analysis, only portions of the models ed. The source documents should be consulted e for the Industrial Source Complex [ISC3] ons; and Volume II - Description of Model

plume equation as the basic transport equation ations given the emission rates for the sources.

ind vertical direction; is of contaminants from the plume; and on, plume rise, mixing in the vertical, and the ates with diameters greater than about 0.1

source at each receptor are summed to obtain stor by the combined source emissions. The n the long-term model, the area surrounding the width corresponding to the sectors of the on, wind speed, and stability. For the present s for wind directions, 6 wind speed categories, and 6 stability n the source are partitioned among the sectors according to the ward the sectors. The concentration fields calculated for each a coordinate system, polar or cartesian) are summed to obtain

### odel

ation in the upwind and crosswind directions, ISC computes air ated downwind of all or a portion of the source area. Because er the area upwind of the receptor location, receptors may be tself, downwind of the area, or adjacent to the area. In the d direction) average concentration is computed by integrating area source algorithm across the sector.

### Model

s of radionuclides at receptor locations, deposition rates are ments for the CA. The dry deposition model calculates the deposition flux) at the surface from a particle plume through deposition flux is calculated as the product of the air conceny at a reference height. The effect of deposition on the ed for. The deposition velocity is computed using a resistance effects of Brownian motion, inertial impaction, and gravita-

# arameter Selection

sources identified in Yucca Flat as described in Chapter 2. inistically using bounding values of model parameters.

# ction

length and width, and the radionuclide flux. Source area distance to the Area 3 RWMS) are given in Chapter 2. The s, or fluxes, is described in the next section. The parameters sition calculations included particle diameter and particle taken as one micron, and the particle density as 2.43 g/cm<sup>3</sup>. The for the dry deposition calculations was taken as 0.01 m dispersion parameters were used in the model. Default values a profile exponents, and vertical temperature gradients were ambient air temperature used in the model was 290 degrees and that the receptors were on a flat terrain, and the mixing 300 ft).

ed primarily from atmospheric testing and from safety shots in of nuclear devices. The ground zero (GZ) soils of almost all

atmospheric tests have been contaminated. Plutonium, scattered by conventional explosives, contaminated the GZs of the safety experiments. Other areas were contaminated from:

- Near-surface cratering tests that dispersed radioactive rock and soil about the GZ.
- Deeper underground tests which inadvertently vented radioactive material to the surface.

Atmospheric and underground tests (including cratering tests) performed in each of the NTS Operational Areas appear in Table A6.1. The total activity on surface soils in the NTS (*Table A6.1*) is estimated at 2,368 Ci. The total Curie content of the areas in Yucca Flat (shaded entries in *Table A6.1*) is 1,495 Ci, about 63 percent of the NTS total. These estimates follow McArthur (1991).

Twenty-eight contaminated soils areas within the operational areas contained in Yucca Flat are identified in McArthur (1991). Table A6.2 lists their areas, sizes, and approximate distances from the Area 3 RWMS. The radionuclide inventory at each source area appears in Table A6.3. The inventory was decay-corrected from the time of the surveys to January 1, 1990. Significant radionuclides for most areas include <sup>241</sup>Am, <sup>238</sup>Pu, <sup>239</sup>Pu, <sup>240</sup>Pu, <sup>60</sup>Co, <sup>137</sup>Cs, <sup>90</sup>Sr, <sup>152</sup>Eu, <sup>154</sup>Eu, and <sup>155</sup>Eu.

Ten of the 28 areas in *Table A6.2* account for 75 percent of the total activity (Table A6.4). These areas, in descending activity order, are SEDAN (Area 10, accounting for about 22 percent of the total inventory); SMOKY (Area 2); WILSON (Area 9); HORNET (Area 3); KEPLER (Area 4); QUAY (Area 7); Yucca Flat (Area 15); BANEBERRY (Area 8); GALILEO (Area 1); and SHASTA (Area 2). Table A6.5 shows the ordered distances of the source areas. Fourteen areas are within about 10,000 m (6.3 mi) of the Area 3 RWMS. Their total activity is 601.3 Ci, about 40 percent of the total for Yucca Flat.

#### A6.4.3.3 Source Area Emissions

The activity flux density from surface soil contamination areas is estimated as:

$$J(t) = \frac{I r e^{-\lambda t}}{A}$$



where

J(t) = the flux density at time t, Ci/m<sup>2</sup>/s;

I = the inventory, Ci;

 $r = the resuspension rate, s^{-1};$ 

 $\lambda$  = radiological decay constant, yr<sup>-1</sup>; and

A = the area of the soil contamination area,  $m^2$ .

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mplex (ISC3) Dispersion Models 454/B-95-003b. U.S. Park, North Carolina.

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d Hydrochemical Framework, Special Reference to the Nevada overnment Printing Office,



7005 5244 4364 4771 13032 11515 13625 12392 305 4286 4027 8769 6189 11412 4267 5527 15471 15987 19125 9872 9900 14462 14379 17504 13619 11904 10064 19138	A6-11

Table A6.3 Radionuclide Inventory (Ci) at Contaminated Soils Areas

Area	Region	Am-241	Pu-238	Pu-239	Pu-240	Co-60	Cs-137	Sr-90	Eu-152	Eu-154	Eu-155
1	Galileo	1	2		1	2.8	4.8	7.2	21.3		0.6
	Hornet	1.3	0.9	<del>                                     </del>	2.04	0.1	3.5	11.7	0	<del></del>	0
	S. Yucca	1.2	2.3	4.72	1.18	0.1	1	1.5	0	<del> </del>	0
	Unsurveyed	0.7	1.3	2.64	0.66	0.1	1.1	1.6	0	0	0
2	Whitney	0.4	1.4	3.84	0.96	1.6	4	11.2	19.4	0.7	0.1
	Shasta	0.7	2.1	4.24	1.06	0.7	10.4	27	0.3	0	·
	Diablo	1	2.7	4.48	1.12	0.4	9	18	0.4	0	0.1
	Sedan	0.8	2.4	5.2	1.3	0.7	5.3	13.1	0	0	0
3	Hornet	3.4	2.3	21.68	5.42	1.8	8.5	28.1	24,4	1.1	0.6
	S. Yucca	0.2	0.1	1.2	0.3	0.1	0.6	2		0	0
	Unsurveyed	1	0.7	6.48	1.62	0.4	5	16.4	9		0
4	Kepler	5.8	11.6	27.84	6.96	3.9	10.8	14	13	♥ 0.9	0.2
	Quay	0.4	0.1	2.4	0.6	0.1	2	4.4	0	0	0
	Unsurveyed	0.4	0.8	2	0.5	0.6	1.3	1.6	0	0	0
7	Quay	1.5	0.4	8.96	2.24	2.1	2,8	6.1	29.9	2.4	0.4
	Unsurveyed	0.7	0.2	3.92	0.98	0.3	3.3	7 7.2	0	0	0
8	Baneberry	0.9	0.7	2.88	0.72	8.9	26.4	<b>}</b> 6.6	0	0	0
	Smoky	15.6	7	85.36	21.34	2.1	13.4	17.1	6	0.4	0.7
	Unsurveyed	0.4	0.3	1.84	0.46	4.2	9.8	13.8	0	0	0
9	Wilson	3.6	1.9	60.48	15.12	1.5	7	13.3	31	2.9	0.4
	Unsurveyed	0.6	0.3	10.88	2.72	∠ 0.3	3.2	6.2	0	0	0
10	Sedan	18.4	18.4	80.88	20.22	<del>2</del> 4.7	83.7	68.4	3	4.2	6
	Unsurveyed	1	1	4.24	1.06	0.6	16	13.1	0	0	0
15	Yucca Flat	2.5	2.1	17.04	4.26	0.3	8.8	12.1	0	9	0
17	Yucca Flat	1.8	2.8	9.04	2.26	1.4	9.2	14	0	0	0
6	S. Yucca	1.7	<i>3</i> :3	6.72	1.28	0.4	3.3	5	0	0	0
11	Plutonium Valley	3.3	0.3	⇒ <sub>23.2</sub>	5.8	0	0.4	0.2	0	0	0
	Pin Stripe	0	70	0	0	0	0.2	0.2	0	<del> </del>	0



Table A6.4 Total Inventory (Ci) at Contaminated Soils Areas

Area	Region	Total	%	Rank	% cum
10	Sedan	327.9	21.93	1	21.93
8	Smoky	169.0	11.30	2	33.23
9	Wilson	137.2	9.17	3	42.40
3	Hornet	97.3	6.51	4	48.91
4	Kepler	95.0	6.35	5	55.26
7	Quay '	56.8	3.80	6	59.06
15	Yucca Flat	56.1	3.75	7	62.81
8	Baneberry	47.1	3.15	8	65.96
1	Galileo	46.9	3.14	9	<i>△</i> 69.10
2	Shasta	46.8	3.13	10	72.23
2	Whitney	43.6	2.92	11	75.14
17	Yucca Flat	40.5	2.71	12	77.85
2	Diablo	37.2	2.49	13	80.34
10	Unsurveyed	37.0	2.47	14	82.81
	Plutonium			Ø,	
11	Valley	33.4	2.23	<b>45</b>	85.05
3	Unsurveyed	31.6	2.11	16	87.16
8	Unsurveyed	30.8	2.06	17	89.22
2	Sedan	28.8	1.93	18	91.15
1	Hornet	27.7	_1.85	19	93.00
9	Unsurveyed	24.2	1562	20	94.62
6	S. Yucca	21.7	1.45	21	96.07
7	Unsurveyed	16.6	₹.11	22	97.18
1	S. Yucca	12.0	0.80	23	97.98
4	Quay	10.0	0.67	24	98.65
1	Unsurveyed	8.1	0.54	25	99.19
4	Unsurveyed	7.2	0.48	26	99.67
3	S. Yucca	₩ 4.5	0.30	27	99.97
11	Pin Stripe	0.4	0.03	28	100.00
Total		1495.4	100		



anked Distances of Source Areas From the Area 3 RWMS

Region	Easting	Northing	Miles	Meters
t	688500	837000	0.2	304.8
veyed	700560	839000	2.5	4027.1
r	687500	851000	2.7	4267.2
ca ca	685500	823080	2.7	4286.4
рса	673500	834000	2.7	4364.1
veyed `	673500	830000	3.0	4770.9
:t	673500	847000	3.3	5244.0
veyed	696030	853000	3.4	5526.6
	675000	853000	3.8	→ 6188.6
o	664588	838780	4.4	7004.6
r	664462	854233	5.4	8769.2
n	682500	869000	6.1	9871.9
veyed	693060	869000	6.2	9899.7
ıium Valley	705000	809000	6.3	10064.2
veyed	654140	854000	<b>A</b> 7.1	11412.3
ı	663323	866030	7.2	11515.1
ca	675000	800000	₩ 7.4	11903.8
	677375	876375	7.7	12391.9
ey	660103	869823	8.1	13031.6
, Flat	644750	<b>850000</b>	8.5	13619.4
<b>,</b>	662634	874146	8.5	13624.7
veyed	691560	884000	8.9	14379.0
	681000	<b>∀</b> 884000	9.0	14461.9
erry	665000	882500	9.6	15471.4
y	674250	887750	9.9	15987.1
. Flat	684500	894350	10.9	17504.2
veyed	674250	898330	11.9	19124.7
ripe	706000	777000	11.9	19137.6

# esuspension Rates for Soil Contamination Areas in Yucca Flat

Resuspension Rate (s <sup>-1</sup> )	Source
1e-10	Shinn et al. (1986) - 3 X Pu Valley Value
2e-14	Shinn et al. (1986) - 3 X Palanquin Value
2e-12	Shinn et al. (1986) - 3 X Little Feller Value

# Deposition Rate

nnual sition Rate 50-Year tclosure Ci/m²)	Air Concentration at 1,000-Year Postclosure (Ci/m²)	Annual Deposition Rate at 1,000-Year Postclosure (Ci/m²)
63e-13	8.84e-18	4.86e-14
76e-15	4.4e-21	2.34e-17
95e-29	1.28e-69	2.87e-72
38e-16	3.52e-27	
14e-15	2.95e-27	145e-23
42e-19	3.18e-39	1.6e-35
82e-23	7.71e-53	4.01e-49
04e-13	162-16	8.83e-13
28e-08	3.826-17	2.11e-13
41e-18	2.81e-37	1.55e-33



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# Appendix 7 Radiological Assessment Method





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ilates total effective dose equivalent (TEDE) as the tor (PDCF) and the concentration of the radionular transport models. The PDCFs are derived from 2) for converting residual contamination into TEDE. re a best-estimate of the PDCF for an average on U.S. Department of Energy (DOE) guidance ribes the derivation of the PDCFs and the

**Dose Conversion Factors** 

ay-specific ratio of TEDE per unit concentration in PDCF has been derived algebraically from the edy and Strenge (1992) for a residential scenario, d. The only consistent change is that radioactive gnored. Radioactive decay during the one-year stake will be minor for the long-lived radionuclides e neglected (Wood et al., 1994).

methods for all scenarios. Parameter values, sent the different scenarios.

s in airas gases or attached to suspended soil ioactivity may occur through inhalation, dermal

l particulates is calculated as:

$$\left| \mathcal{D}_{o,m} \right| EF \ V_m \ t_m \right] \tag{A7.1}$$

on PDCF for radionuclide j, mrem/yr per Ci/g soil; ose factor (DF) for radionuclide j, mrem/Ci; ime intervals with different ventilation rates and g levels, dimensionless; loading during time interval m, g/m³; ss loading during time interval m, g/m³; factor, dimensionless;

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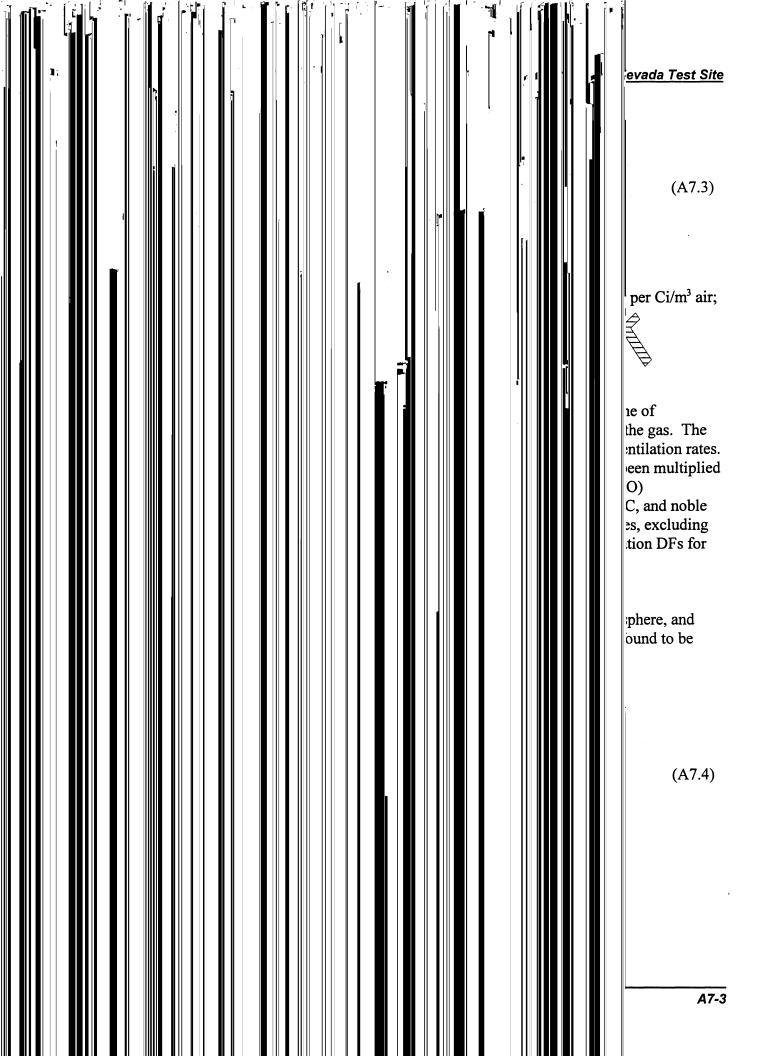
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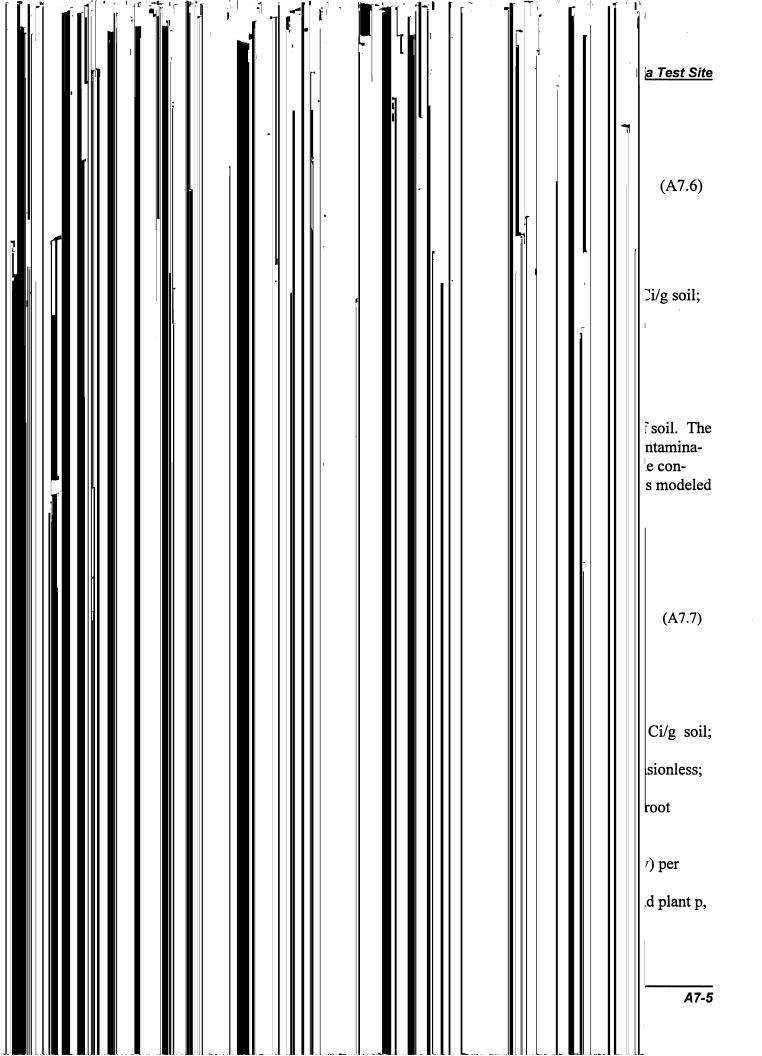
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(A7.2)

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i, the fraction of ingested plants grown in the ate, and the concentration ratio of the radio-soil concentration ratio is calculated as the sum le-derived dry weight concentration ratio.

s calculated using a specific activity model as:

(A7.8)



n of plant p, kg H in plant/kg plant (wet); y ratio, Ci/kg H in plant per Ci/kg H in soil unity); and ter content of soil, kg H<sub>2</sub>O/kg soil.

of H in soil water is equivalent to the specific

nown to include a gaseous pathway, which may reumstances (Amiro et al., 1991). However, estimating the concentration in air. Rather than ion ratios based on lysimeter experiments which chosen (Sheppard et al., 1991).

### **PDCF**

lated as:

$$\left\{ \sum_{p=1}^{S} \left[ Q_p x_p \left( ML_{\nu,p} + B_{j,\nu,p} \right) W_{\nu,p} \right] \right\} \right\}$$

on PDCF for radionuclide j, mrem/yr per Ci/g

at produced at home,

e j, mrem/Ci; n model (beef, milk, poultry and

unimal product q, l/yr for milk and hal products; r for radionuclide j and animal q, wet) for all other animal products; odel (forage, hay, and grain),

plant p, kg (wet)/d; plant p that is contaminated,

surfaces, Ci/kg plant (dry) per

tios for radionuclide j and plant p, oil dry);

nt type p, dimensionless; ake that is soil, kg (dry) soil/kg

age, dimensionless;
forage, kg (wet)/d; and
forage that is contaminated,

the product of the fraction of the insumption rate, and the fractional contamination is transferred to the and soil. Forage, hay, and grain ition.

ted using a specific activity model

ıH

 $\left. \frac{t_{ff}}{-} \right\}$ 

(A7.10)

H, mrem/yr per Ci/g soil;

1 from contaminated area,

roduct q, l/yr for milk and acts;

, kg H/kg (wet) animal

I in animal per Ci/kg H in cg (wet)/d; at is contaminated,

<sup>8</sup>H and plant p, Ci/kg plant

, Ci/kg plant (dry) per

), dimensionless; p, d; is soil, kg (dry) soil/kg

ensionless; g (wet)/d; at is contaminated,

e, d; g (wet plant); and lry) soil.

roduct of the fraction of nption rate, the fractional lant intake. Soil stion of forage, hay, grain, ot uptake and soil

ng a specific activity model



em/yr per Ci/g soil;

contaminated area,

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/kg (wet) animal

imal per Ci/kg C in

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ensionless;

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nless; t)/d;

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) plant; and

ne product of the fraction of sumption rate, the fractional in plant intake. Soil ngestion of forage, hay, grain, a root uptake, CO<sub>2</sub> fixation,

version factor (SDCF) and the the sum of all the individual SDCF is specific to a



of a small rural community.

ecause the residents are not
t to be engaged in commercial
la do not engage in any
The performance objectives
To as the community

ada do engage in agricultural dents will cultivate a small cond scenario, referred to as icultural pathways. This jed by uncertainty in the

hdwater. The community dwater for irrigation of a s described in Appendix 1 han the compliance period of nination in the aquifer.

r.			<u>rest Site</u> the
			released
		F	7.12)
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			ters (m)  1,  n,  ft) 5 be  may be oth 1 limited 1 limit
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gaseous radionuclide concentration is the maximum concentration in air at 100 m (330 ft) from the site boundary. The maximum concentration in air was estimated for the south sector.

The TEDE for all pathways is given by:

$$TEDE(t) = \sum_{j=1}^{M} \left[ C_{s,j}(t) \left( PDCF_{H,j} + PDCF_{EX,j} + PDCF_{GS,j} \right) + C_{al00,j}(t) \left( PDCF_{GH,j} + PDCF_{lM,j} \right) \right]$$
(A7.13)

where

TEDE(t) = annual total effective dose equivalent at time t, mrem/yr;

 $PDCF_{EX,i}$  = pathway dose factor for radionuclide j for external exposures to

soil, mrem/yr per Ci/g soil; and

 $PDCF_{GS, i}$  = pathway dose factor for radionuclide j for soil ingestion,

mrem/yr per Ci/g soil.

The all-pathways TEDE is the sum of the dose from soil inhalation, external exposure, inadvertent soil ingestion, gas inhalation, and gas inhalation pathways. The soil and air concentration are the concentrations at 100 m (330 ft) as described above.

The community scenario was also evaluated assuming the resident engages in small-scale noncommercial agriculture. Water-dependent pathways are not included because results indicate that radionuclide from waste will not reach the aquifer within 1,000 years and contamination data from underground testing are not available. Residents of the rural community with agriculture are exposed to radioactivity released from the site through:

- Inhalation of resuspended soil particulates,
- Inhalation of gaseous radionuclides,
- Immersion in gaseous radionuclides,
- External irradiation from radionuclides in soil,
- Inadvertent ingestion of soil,
- Ingestion of vegetables,
- Ingestion of beef and milk from range-fed cattle, and
- Ingestion of meat and eggs from range-fed poultry.

The TEDE from atmospheric pathways for the community scenario with agriculture is calculated as in Equation A7.12. Parameters contributing to the PDCFs have been adjusted to reflect exposure to higher levels of suspended particulates while cultivating a garden and longer periods of time spent outdoors.

E from all pathways for the community with agriculture scenario is given by:

$$= \sum_{j=1}^{M} \left[ C_{s,j}(t) \left( PDCF_{H,j} + PDCF_{EX,j} + PDCF_{GS,j} + PDCF_{VG,j} + PDCF_{AG,j} \right) \right]$$

$$+ C_{al00,j}(t) \left( PDCF_{GH,j} + PDCF_{IM,j} \right) \right]$$

EDE(t) = annual total effective dose equivalent at time t, mrem/yr;

DCF<sub>VG, j</sub> = pathway dose factor for radionuclide j for vegetable ingestion,

mrem/yr per Ci/g soil; and

DCF<sub>AG, i</sub> = pathway dose factor for radionuclide j for animal product

ingestion, mrem/yr per Ci/g soil

athways TEDE is the sum of the dose from soil inhalation, external exposure, nt soil ingestion, vegetable ingestion, animal product ingestion, gas inhalation, and exist pathways. As before, the environmental concentrations are those for the 100-t) boundary.

### Intruder Scenarios

der scenarios assume the same land use and exposure pathways as the community with agriculture used for the members of the public. The intruder, however, is to exhume waste from the site and create a contaminated area. Two chronic intruder were evaluated: the intruder-agriculture and the postdrilling scenario. The agriculture scenario assumes the intruder excavates a basement at the site. The ng intruder scenario assumes that the intruder drills a water well through the waste. cenarios, the intruder creates a surface contamination zone with the exhumed are contamination. The intruder is assumed to live directly over the waste disposal in the contaminated zone.

der is assumed to be a member of a small rural community that commutes five days work at an off-site location. The intruder is assumed to be exposed to radioactivity or exhumed from the site through:

tion of resuspended soil particulates, tion of gaseous radionuclides, sion in gaseous radionuclides, al irradiation from radionuclides in soil, retent ingestion of soil, ion of vegetables,

+ 
$$PDCF_{VG,j}$$
 +  $PDCF_{AG,j}$  )



contaminated zone created by

r j in air above the disposal unit at

the intruder-agriculture scenario rio assumes an external DF for s the DF for a 0.15-m- (0.50-ft)griculture. Derivation of the soil

is assumed to be 3 m (9.8 ft) to 3.0 m (8.2 to 9.8 ft) deep, at U-3ah/at, the intruder is or to excavation, radioactivity is sumed earlier for upward release: tile radionuclides are assumed to ribed in Appendix 4.

00 square meters (m<sup>2</sup>)
. house. The total volume
n<sup>3</sup>) (21,000 cubic feet [ft<sup>3</sup>]). The
2,500 m<sup>2</sup> (27,000 ft<sup>2</sup>). This area
(NRC, 1981; Kennedy and
ad over 2,500 m<sup>2</sup> (27,000 ft<sup>2</sup>)
se this is thicker than the zone
f the soil is assumed. The conn of the shallow and deep soil
d from each compartment as:

Assessment/Composite Analysis

$$C_{cz,j}(t) = \frac{x_3 C_{3,j}(t) + x_4 C_{4,j}(t)}{x_3 + x_4}$$
 (A7.16)

where

x<sub>3</sub> = thickness of the deep soil layer, m; x<sub>4</sub> = 'thickness of shallow soil layer, m;

 $C_{3,j}(t)$  = concentration of radionuclide j in the subsurface soil layer, Ci/g; and

 $C_{4,i}(t)$  = concentration of radionuclide j in the shallow soil layer, Ci/g.

The surface and subsurface soil concentrations of nonvolatile radionuclides are the mean values estimated by the nonvolatile radionuclide release model (see Appendix 4). The concentration of volatile radionuclides in air above the disposal site is estimated as described in Appendix 4.

Intruder-agriculture scenarios are often analyzed for thinner caps where the intruder directly contacts buried waste. To evaluate the effects of this event, the intruder-agriculture scenario was analyzed assuming that the intruder excavates 0.6 m (1.9 ft) into the waste as assumed at the Area 5 Radioactive Waste Management Site (RWMS) (Shott et al., 1998). This case is analyzed as a sensitivity case requested by reviewers. It is a bounding case because it is physically impossible. For this case, the contaminated zone soil concentration was calculated as:

$$C_{cz,j}(t) = \frac{x_3 C_{3,j}(t) + x_4 C_{4,j}(t) + 0.6m C_{2,j}(t)}{x_3 + x_4 + 0.6m}$$
(A7.17)

where

 $C_{2,j}(t)$  = concentration of radionuclide j in the shallow waste compartment, Ci/g.

The Postdrilling Intruder Scenario. The postdrilling intruder scenario assumes that an intruder drills a water well through the disposal site and creates a contaminated area with the drill cuttings. The contaminated drill cuttings are assumed to be indistinguishable from soil. The contaminated zone soil concentration is calculated as:

$$C_{cz,j}(t) = C_{s,j}(t) + \frac{C_{w,j}(t) \pi r^2 t_w f_d}{A_{cz} D_{cz} \rho}$$
 (A7.18)

# Nevada Test Site

minated zone, Ci/g; w soil

 $/m^3$ ;

contamination from cuttings. The time-onvolatile radio-aste concentration e borehole is be 7.7 m (25 ft), the y design factor is The facility design 2 for U-3ah/at. The previous PAs volume of drill roximately 0.015 m mixed to the depth e contaminated

les in air above the

rural community rural community gain as the product e concentrations of al contamination.

in air, soil, and ive contamination the Area 3 RWMS on sites in Yucca pheric transport. In sed in U-3ax/bl.

A, and is evaluated hit is assumed to

'Composite Analysis

soils by the same processes as assumed for U-3ah/at and lose is consumption of groundwater contaminated by nination from the U-3ah/at disposal unit is not expected 1 the compliance period, there is no potential for the lon and contamination released from the U-3ah/at ion from prior underground testing is not evaluated lining in this source. Therefore, this source is not

ulated as:

ximum surface soil activity concentration among the RWMS disposal units (U-3ax/bl, U-3ah/at, or U-3bh),

RNET GZzoil activity concentration of radionuclide j,

concentration of radionuclide j at the Area 3 RWMS I from residual soil contamination from remote sites in Flat, Ci/m³ air; and alation PDCF for suspended particulates in air, mrem/yr m³ air.

the HORNET GZ and the Area 3 RWMS. The rne soil transported from more remote sites in Yucca al Source Complex (ISC) model as described in remote sites was found to be negligible compared to the IORNET GZ and the disposal unit caps and was not borne contamination from remote sites was calculated Appendix 6. The atmospheric concentration of gases centration at 100 m (330 ft) from U-3ah/at, U-3ax/bl, and numental media in the composite analysis are calculated

rada Test Site (A7.18)ne Area 3 radionuclide radionuclide dionuclide j, /m<sup>3</sup>; ide j at 100 ide j at 100 j at 100 m, y McArthur h are dix 4. The uclide ncentrations tions from sets of scenario lture erences osite Analysis

### Nevada Test Site

r, the assumed the inclusion of nearly equivalent

low, except for data to determine ptions are made. listributions. vere assigned

garden). The values for the Las ean PM<sub>10</sub> values tter with an aeroparticulate matter tion, PM<sub>10</sub> is eposition in the mostly in the 10µm fraction these larger e element. The f<sub>1</sub> luids (ICRP, lation and gested. Therefore, in Las Vegas is pading values for lightly less than ysis. The Las hat will occur with he distribution is lard deviation of

T GZ. Enrichment nsion at atmoy Shinn *et al*.
listributed with a

umination derived eported that the with a geometric ennedy and lated as the product of the indoor soil loading assumed to be triangular. While indoors, oor mass loading plus the indoor mass factors were assumed to be correlated with a

It on the activity being performed and the ommonly recommended for radiological 1992). This is considered a conservative uniformly between a high background level of

physical activity levels for each time period. have been estimated by Layton (1993), based utions are assumed to be uniform, with ranges issumed level of physical activity. The te, the indoor period assumes a sedentary umes light activity, and the gardening period on rates are assumed to be correlated with a

er commutes to a remote work location. The ar at work. The resident is assumed to spend or 2,922 hours per year. All remaining time of activity patterns of adults have suggested ercent of the time that they are at home tion Protection [NCRP], 1984). Therefore, rmly between 60 and 95 percent of the total lated as the remaining time. In the scenarios med to spend a fixed time of 100 hours per

re the same as in the soil inhalation pathway,

re the same as in the soil inhalation pathway,

vay common with the soil inhalation pathway actors. Members of the public are assumed to f the public (MOP) scenarios all assume an ninated soil layer. The postdrilling intruder aminated soil layer and uses the DF for this

Performance Assessment/Composite Analysis

Isumes a 0.15-m- (0.50-ft)-thick contaminated soil layer and uses the DF for this The intruder-agriculture scenario assumes a 0.24-m- (0.80-ft)-thick contaminated PDCF for the intruder-agriculture scenario assumes external DFs for a uniform with depth. Contamination at the HORNET GZ is assumed to be distributed with depth.

uission factor is assumed to be fixed at 1.0 for all time periods spent outdoors. on factors for indoor occupancy are dependent on the construction materials used ence and its design. Transmission factors for one-story residences have been range from 0.06 to 0.27 (NCRP, 1984). Motor vehicles, which may approximate ome, have been reported to have factors ranging from 0.15 to 0.6 (NCRP, 1984). nd Strenge (1992) recommend 0.33 as a representative value for a residence. The smission factor is assumed to be triangular, with a mode of 0.33 and a range from . The bulk density of soil is assumed to be fixed at the mean value reported from erization reports.

### Inadvertent Soil Ingestion Pathway

e been reported to ingest from 0.005 to 0.077 g/day of soil (Kennedy and Strenge, alue of 0.05 g/day has been reported as a representative mean value. Accordingly, tion is assumed to be triangular with a mode of 0.05 g/day and range from 0.005 day.

Agricultural Pathways

urrent land use in southern Nevada, the occurrence of agriculture at the Area 3 expected to be a low-probability event. Agricultural pathways have been included logical assessment as a part of the sensitivity and uncertainty analysis. All agriameters are assigned fixed parameter values, except for the fraction of the diet uced in the contaminated area. The scenarios assume that the resident or the rks full time at a remote location and is therefore not engaged in agriculture on a usis. Gardening of investock production in Yucca Flat would be difficult. of home-grown vegetables and fruits does occur in areas surrounding the NTS ental Protection Agency [EPA], 1984). Although the lower elevations of Yucca een reported to have some of the best agricultural soils on the NTS, there are still water retention and soil fertility limitations (Richard-Haggard, 1983). Intense in conditions, and extreme temperatures make cultivation of some crops infeasible the growing season for others. Therefore, it is assumed that if the resident agriculture at the site, it will be small-scale and noncommercial.

s with agricultural pathways, the resident is assumed to cultivate a small vegetable gional data on the production of home-grown vegetables are not available. The ) has suggested that individuals cultivating a home garden typically produce of their vegetable intake. Given the difficulties of vegetable gardening in southern typical vegetable production is assumed to be an upper limit for this site. A 52-) garden plot would be sufficient to support 20 percent of the vegetable intake for

### Nevada Test Site

es, root crops, amercial

the sum of a entration ratios he product of estimated that osition. They ples is 0.096. t uptake of Pu is ables and forage, 92), soil mass

sumed to ed to be ope of have a diet 1 uncontamiwhile foraging. aminated forage be very mixed , fourwing tfir (*Ephedra* e NTS have per hectare (ha) s [ac]), the size e consumption y an intruder . As the area of ived from the capable of producing beef r annual n be supported his site.

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#### Test Site

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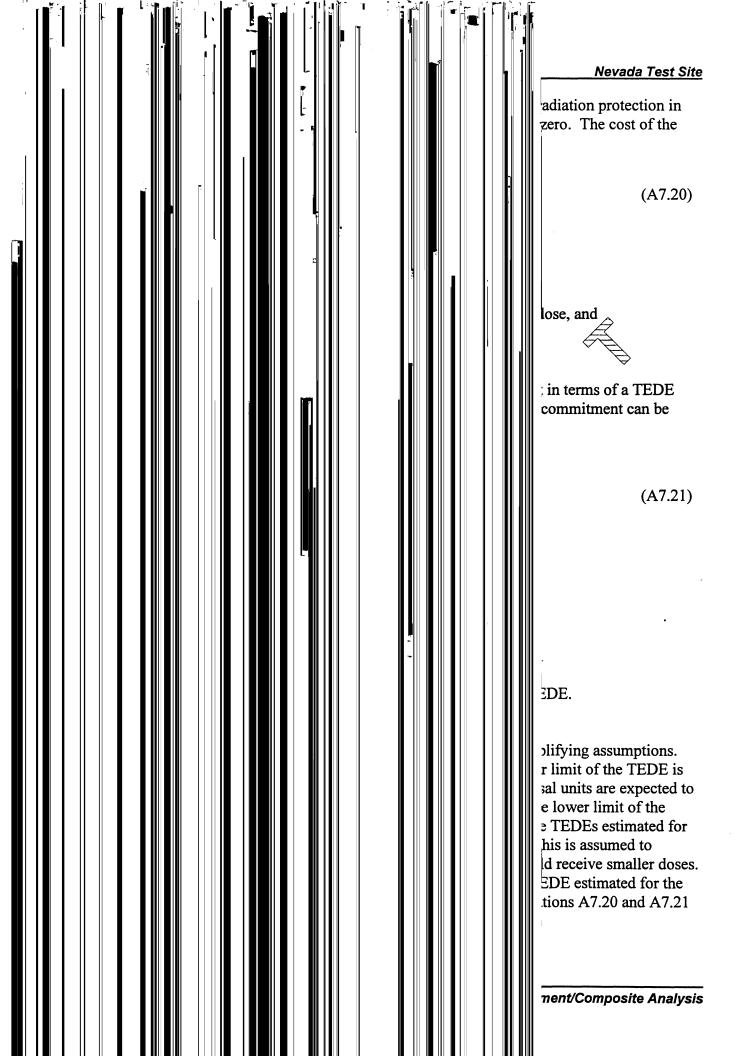
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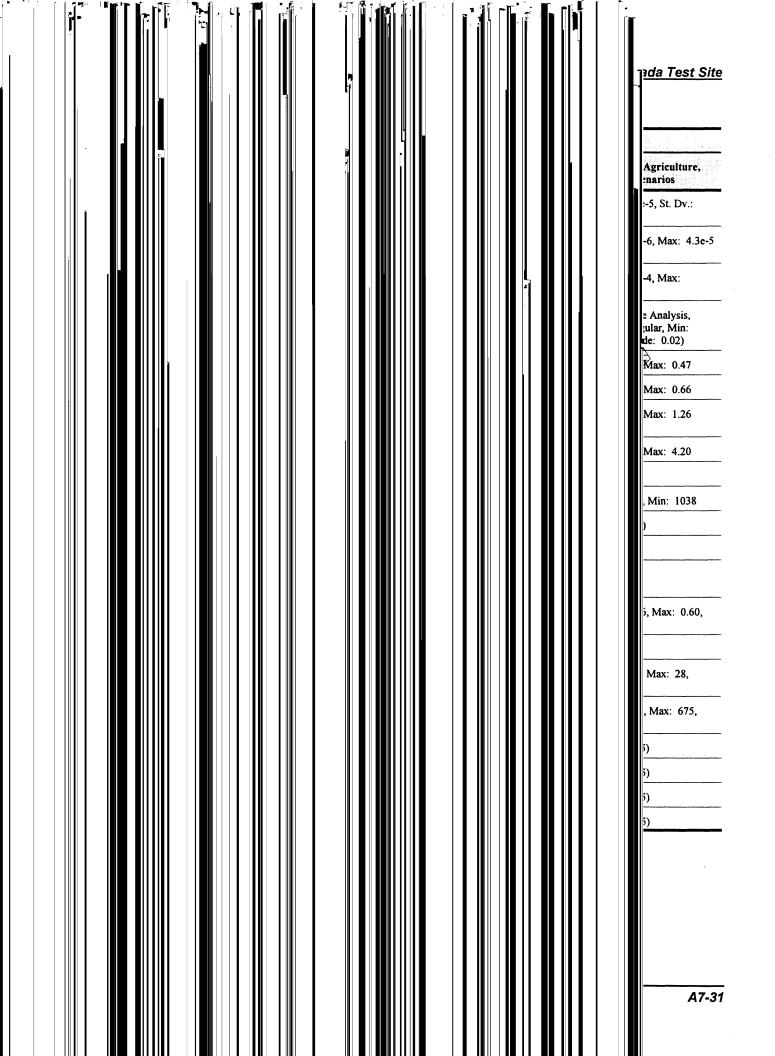


Table A7.2 Agricultural Pathway Parameters for Water-Independent Pathways

Parameter	Units	Value	Source
Gravimetric Moisture Content, S <sub>H</sub>	g/g	0.13	Bechtel Nevada (1996a,b; 1997)
Leafy Plant Mass Loading, ML, p	kg (dry) soil/kg (dry) plant	0.1	Martin and Bloom (1980)
Other Plant Mass Loading, ML,,	kg (dry) soil/kg (dry) plant	0.01	Martin and Bloom (1980), Kennedy and Strenge (1992)
Leafy Veg. Dry/Wet Ratio, W <sub>v,p</sub>	kg (dry)/kg(wet)	0.2	Kennedy and Strenge (1992)
Other Veg. Dry/Wet Ratio, W <sub>v,p</sub>	kg (dry)/kg(wet)	0.25	Kennedy and Strenge (1992)
Fruit Dry/Wet Ratio, W <sub>v, p</sub>	kg (dry)/kg(wet)	0.18	Kennedy and Strenge (1992)
Grain Dry/Wet Ratio, W <sub>v,p</sub>	kg (dry)/kg(wet)	0.91	Kennedy and Strenge (1992)
Leafy Veg. Fraction H, f <sub>H, p</sub>	kg H/kg (wet) plant	0.1	Kennedy and Strenge (1992)
Other Veg. Fraction H, f <sub>H, p</sub>	kg H/kg (wet) plant	0.1	Kennedy and Strenge (1992)
Fruit Fraction H, f <sub>H,p</sub>	kg H/kg (wet) plant	0.1	Kennedy and Strenge (1992)
Grain Fraction H, f <sub>H,p</sub>	kg H/kg (wet) plant	0.068	Kennedy and Strenge (1992)
Soil Fraction H, f <sub>H, d</sub>	kg H/kg wet soil	0.014	Gravimetric Water Content/9
Forage/Hay Fraction C, f <sub>C,p</sub>	kg C/kg (wet) forage	0.09	Kennedy and Strenge (1992)
Grain Fraction C, f <sub>C,p</sub>	kg C/ kg (wet) grain	0.4	Kennedy and Strenge (1992)
Cattle Forage Consumption Rate, Q	kg (wet)/day	30	Martin and Bloom (1980)
Cattle Grain Consumption Rate, Q	kg (wet)/day	3	Kennedy and Strenge (1992)
Cattle Hay Consumption Rate, Q	kg (wet)/day	14	Kennedy and Strenge (1992)
Fraction of Cattle Forage as Soil, Q	kg (dry)soil/kg (dry) forage	0.063	Smith (1977)
Poultry Forage Consumption Rate, Q	kg (wet)/day	0.13	Kennedy and Strenge (1992)
Poultry Grain Consumption Rate, Q,	kg (wet)/day	0.09	Kennedy and Strenge (1992)
Poultry Hay Consumption Rate, Q,	kg (wet)/day	0	Kennedy and Strenge (1992)
Fraction of Poultry Forage as Soil, Q	kg (dry)soil/kg (dry) forage	0.1	Kennedy and Strenge (1992)
Days Cattle Consume Forage, t, r	days/yr	365.25	Kennedy and Strenge (1992)
Days Cattle Consume Grain, t, p	days/yr	365.25	Kennedy and Strenge (1992)
Days Cattle Consume Hay, t, p	days/yr	365.25	Kennedy and Strenge (1992)
Days Poultry Consume Forage, t, f	days/yr	365.25	Kennedy and Strenge (1992)
Days Poultry Consume Grain, t, p	days/yr	365.25	Kennedy and Strenge (1992)
Days Poultry Consume Hay, t, p	days/yr	365.25	Kennedy and Strenge (1992)
Fraction of Cattle Forage Intake Contaminated, x <sub>f</sub>	Dimensionless	0.006	Richard-Haggard (1983)

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Value	Source
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1.00e-02	1.00e-03	1.00e-03	2.00e-03	0.00e+00	4.00e-03	1.00e-02	1.50e-03	3.00e-05	2.00e-02	1.00e-02	1.00e-02	1.00e-03	1.00e-03	1.00e-02	7.00e-03	3.50e-04	2.00e-05	2.00e-05	2.00e-05	2.00e-05
4.40e-U2	1.00e-03	1.00e-03	5.00e-01	0.00c+00	8.50c+00	2.00e+00	3.50e-02	6.40e-05	3.10e-04	3.00e-02	3.00e-04	8.40e-01	2.00e-01	1.80e-02	4.40c+00	8;10e-04	4.00e-03	4.00e-03	4.00e-03	4.00e-03
7.00e-04	6.00e-03	6.00e-03	2.00e-02	0.00 <del>c+</del> 00	1.50e-02	1.50e-02	3.00e-04	5.50e-03	2.50e-01	(\$\\$0e-03	4.00e-03	5.50e-04	8.00e-02	7.00e-03	2.00e-02	1.50e-04	5.00e-03	5.00e-03	3.50e-03	4.50e-03
3.50e-01	3.00e-02	3.00e-02	3.70e-03	0,00 <del>c+</del> 00	72/S0e-02	7.00e-02	1.30e-01	5.00e-04	5.00e-03	7.30e-01	4.00e-02	1.50e-01	6.00e-03	5.00e-02	2.60e-02	1.50e-02	4.00e-03	4.00e-03	4.00e-03	4.00e-03
10-905.E	€ 6.00e-02	6.00e-02	7.00e-03	0.00e+00	2.50e-02 ⊲	7.00e-02	1.70e-01	5.00e-04	5.00e-03	1.50e+00	4.00e-02	1.50e-01	6.00e-03	5.00e-02	2.20e-01	1.50e-02	4.00e-03	4.00e-03	4.00e-03	4.00e-03
3.50e-01	6.00e-02	6.00e-02	4.00e-02	0.00e+00	2.50e-02	7.00e-02	8.10e-01	5.00e-04	5.00e-03	1.10e+00	4.00e-02	1.50e-01	6.00e-03	5.00e-02	4.90e-02	1.50e-02	4.00e-03	4.00e-03	4.00e-03	4.00e-03
3.50e+00	2.80e-01	2.80e-01	8.10e-02	0.00e+00	2.50e-02	1.50e-01	1.60e+00	2.00e-03	2.00e-02	4.40e+01	1.50e-01	5.50e-01	3.00e-02	3.40e-03	1.30e-01	1.50e-01	1.00e-02	1.00e-02	1.00e-02	1.00e-02
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3.00e-02	4.00e-03	4.00e-03	4.00e-03	1.20e+00	4.00e-03	1.50e-04	2.00e-04	4.00e-03				
2.50e-04	2.50e-05	6.00e-06	1.00e-05	2.00e-04	5.50e-05	5.00e-07	3.50e-06	3.50e-06				27
1.20e-03	3.50e-04	3.40e-05	2.50e-04	1.30e-03	2.70e-03	2.60e-05	5.90e-05	2.10e-05		<b>\</b>		

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ors (from Eckerman and Ryman, 1993; Eckerman et al., 1988)

ion I)	Air Immersion DF (Sv/s per Bq/m³)	Ingestion DF (Sv/Bq)	External DF (Sv/s per Bq/m³) 15 cm	External DF (Sv/s per Bq/m³) Uniform
	3.310e-19	1.73e-11	0.00e+00	0.00e+00
	1.120e-17	1.26e-09	5.67e-21	5.76e-21
	2.240e-19	5.64e-10	7.20e-23	7.20e-23
	1.360e-13	3.94e-09	7.73e-17	9.32e-17
	2.230e-17	8.18e-10	1.22e-20	1.28e-20
	9.100e-18	0.00e+00	0.00e+00	4.62e-21
	8.050e-15	5.02e-09	4.57e-18	5.57e-18
	0.00e+00	3.44e-10	0.00e+00	0.00e+00
	1.260e-13	7.28e-09	7.25e-17	8.68e-17
	0.00e+00	5.67e-11	0.00e+00	0.00e+00
	0.00e+00	1.56e-10	0.00e+00	0.00e+00
	1.190e-16	0.00e+00	0.00e+00	7.65e-20
	3.030e-19	2.35e-09	9.96e-23	9.96e-23
	1.820e-18	1.33e-09	7.52e-22	7.54e-22
	1.980e-16	4.14e-08	1.24e-19	1.32e-19
	0.00e+00	4.48e-10	0.00e+00	0.00e+00
	4.440e-18	1.41e-10	5.57e-22	5.57e-22
	7.700e-14	1.93e-09	4.53e-17	5.18e-17
	1.620e-18	3.95e-10	6.70e-22	6.72e-22
	0.00e+00	4.04e-11	0.00e+00	0.00e+00
	1.450e-18	4.70e-08	6.05e-22	6.07e-22
	6.940e <sub>7</sub> 18	4.35e-08	3.42e-21	3.47e-21
	6.020e-17	4.19e-10	1.05e-20	1.05e-20
	9.630e-14	5.70e-09	5.66e-17	6.34e-17
	3.800e-16	7.46e-08	6.93e-20	6.93e-20
	5.650e-19	1.91e-09	2.05e-22	2.05e-22
	2.730e-14	1.35e-08	1.62e-17	1.83e-17
	1.780e-14	9.19e-10	9.880e-18	1.06e-17
	3.610e-20	1.05e-10	5.27e-24	5.27e-24
$\supset$	7.170e-14	1.72e-09	4.18e-17	4.67e-17
-	5.650e-14	1.75e-09	3.22e-17	3.75e-17
	0.00e+00	4.34e-08	0.00e+00	0.00e+00
	6.140e-14	2.58e-09	3.52e-17	4.11e-17
	1.420e-15	1.51e-09	7.18e-19	8.38e-19
	8.970e-17	1.97e-06	3.19e-20	3.27e-20
	7.540e-14	1.48e-09	4.34e-17	5.02e-17
	8.860e-14	3.58e-07	5.05e-17	5.99e-17
	4.780e-14	3.89e-07	2.76e-17	3.20e-17
	1.850e-14	3.99e-06	1.01e-17	1.08e-17
	8.030e-14	2.18e-07	4.41e-17	5.46e-17
	1.500e-14	1.09e-06	7.90e-18	8.55e-18
-	1.740e-17	1.48e-07	6.39e-21	6.47e-21
	8.720e-18	7.38e-07	2.78e-21	2.79e-21
	1.720e-15	2.86e-06	9.62e-19	1.02e-18
	1.420e-17	3.54e-07	4.77e-21	4.83e-21

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ilation lq)	Air Immersion DF (Sv/s per Bq/m³)	Ingestion DF (Sv/Bq)	External DF (Sv/s per Bq/m³) 15 cm	External DF (Sv/s per Bq/m³) Uniform
F00	1.630e-17	7.81e-08	7.24e-21	7.48e-21
<b>⊦0</b> 0	7.630e-18	7.66e-08	2.14e-21	2.15e-21
<b>⊩</b> 00	7.720e-15	7.23e-08	3.94e-18	4.06e-18
<b>)</b> -00	5.010e-18	7.26e-08	1.14e-21	1.15e-21
ŀ00	1.210e-15	7.25e-08	6.36e-19	7.08e-19
F00	1.040e-14	1.20e-06	5.58e-18	5.88e-18
<b>⊩00</b>	4.880e-18	1.34e-08	8.07e-22	8.10e-22
<b>+00</b>	4.240e-18	1.40e-08	1.52e-21	1.58e-21
H00	4.750e-18	1.40e-08	7.84e-22	7.85e-22
H00	7.250e-20	2.07e-10	3.15e-23	3.16e-23
+00	4.010e-18	1.33e-08	6.85e-22	6.85e-22
+00	1.630e-14	1.70e-08	9.54e-18	1.09e-17
+00	8.180e-16	9.84e-07	2.34e-19	2.34e-19
+00	9.870e-15	9.80e-07	4.66e-18	4.79e-18
+00	5.690e-18	3.10e-08	9.07e-22	9.15e-22
+00	5.880e-15	6.79e-07	3.02e-18	3.12e-18
+00	4.910e-18	5.45e-07	6.74e-22	6.74e-22
+00	3.960e-15	1.01e-06	1.80e-18	1.82e-18
+00	4.460e-18	1.00e-06	6.22e-22	6.22e-22
+00	1.600e-14	9.24e-07	9.22e-18	9.96e-18
+00	3.390e-18	3.68e-06	4.70e-22	4.70e-22





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noading (0.63), Ventilation Rates (0.58), (0.44)
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	ome Grown (0.85), Outdoor/Indoo
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ssessment/Composite Analysis

Table A7.9 SDCFs for the HORNET GZ

.,,	cn.c-	a <b>n</b>	mrem/yr per	0 7 6 7 12	
Nuclide	Mean SDCF	S. Dev.	unit below	Sensitive Parameters (Spearman Rank Correlation Coefficient)	
SDCFs for the HORNET GZ					
<sup>14</sup> C	1.19e10	4.85e9	Ci/g soil	Fraction of Animal Products Home Produced (0.82), Fraction of Vegetable Intake Home Grown (0.55)	
<sup>∞</sup> Co	5.81e12	1.28e12	Ci/g soil	Indoor Transmission Factor (0.77), Indoor Occupancy (-0.62)	
90Sr+D	4.24e11	2.08e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.99)	
<sup>99</sup> Tc	1.38e11	6.50e10	Ci/g soil	Fraction of Animal Products Home Produced (0.97)	
<sup>126</sup> Sn+D	4.25e12	9.34e11	Ci/g soil	Indoor Transmission Factor (0.76), Indoor Occupancy (-0.61)	
129 <u>I</u>	1.45e11	5.61e10	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.98)	
<sup>137</sup> Cs+D	1.27e12	2.70e11	Ci/g soil	Indoor Transmission Factor (0.77), Indoor Occupancy (-0.62)	
<sup>152</sup> Eu	2.50e12	5.52e11	Ci/g soil	Inadvertent Soil Ingestion Rate (1.00)	
<sup>154</sup> Eu	2.75e12	6.06e11	Ci/g soil	Indoor Transmission Factor (0.77), Indoor Occupancy (-0.62)	
<sup>210</sup> Pb+D	8.74e11	3.71e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.97)	
<sup>226</sup> Ra+D	4.18e12	8.83e11	Ci/g soil	Indoor Transmission Factor (0.76), Indoor Occupancy (-0.62)	
<sup>228</sup> Ra+D	2.33e12	4.76e11	Ci/g soil	Indoor Transmission Factor (0.75), Indoor Occupancy (-0.61)	
<sup>227</sup> Ac+D	2.10e12	6.14e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.94)	
<sup>228</sup> Th+D	3.72e12	8.04e11	Ci/g soil	Indoor Transmission Factor (0.76), Indoor Occupancy (-0.62)	
<sup>229</sup> Th+D	9.44e11	2.03e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.78), Indoor Transmission Factor (46), Indoor Occupancy (-0.37)	
<sup>230</sup> Th	5.17e10	2.24e10	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.98)	
<sup>232</sup> Th	2.52e11	1.11e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.98)	
<sup>231</sup> Pa	9.45e11	4.18e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.99)	
<sup>233</sup> U	4.97e10	1.88e10	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.92), Fraction of Anima Products Home Produced (0.36)	
<sup>234</sup> U	4.84e10	1.84e10	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.92), Fraction of Anima Products Home Produced (0.36)	
<sup>235</sup> U+D	3.17e11	6.15e10	Ci/g soil	Indoor Transmission Factor (0.74), Indoor Occupancy (-0.60)	
<sup>238</sup> U+D	9.28e10	1.99e10	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.77), Indoor Transmission Factor (0.31)	
<sup>236</sup> U	4.58e10	1.74e10	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.92), Fraction of Anima Products Home Produced (0.36)	
<sup>237</sup> Np+D	9.10e11	2.69e11	Ci/g soil	Fraction of Vegetable Intake Home Grown (0.95)	
<sup>238</sup> Pu	1.11e10	5.01e9	Gi/g soil	Enrichment Factor (0.86), Fraction of Vegetables Home Grown (0.39)	
<sup>239</sup> Pu	1.18e10	5.34e9	Ci/g soil	Enrichment Factor (0.86), Fraction of Vegetables Home Grown (0.39)	
<sup>240</sup> Pu	1.18e10	5.34e9	Ci/g soil	Enrichment Factor (0.86), Fraction of Vegetables Home Grown (0.39)	
<sup>241</sup> Pu	1.35-63	8.49e7	Ci/g soil	Enrichment Factor (0.88), Fraction of Vegetables Home Grown (0.36)	
<sup>241</sup> Am	3.1901	1.43e11	Ci/g soil	Fraction of Vegetables Home Grown (0.99)	

sheet Result to RESRAD 5.61 Soil Ingestion, Plant Ingestion, Beef

ngestion	Beef Ingestion	Milk Ingestion
le-01	9.99e-01	9.99e-01
e-01	9.99e-01	9.99e-01
le-01	9.98e-01	9.99e-01
e+00	1.00e+00	1.00e+00
e+00	1.02e+00	1.01e+00
e-01	9.99e-01	9.99e-01
e+00	1.00e+00	1.00e+00
e-01	9.90e-01	9.90e-01
e-01	9.99e-01	1.00e+00
e-01	1.00e+00	1.00e+00
e-01	1.00e+00	9.99e-01
)e <b>-0</b> )	1.00e+00	1.00e+00
€01∕2	1.01e+00	1.00e+00
e+00	1.00e+00	1.00e+00
)e-01	1.00e+00	1.00e+00
ie-01	9.95e-01	9.96e-01
e-01	1.02e+00	1.01e+00
le-01	1.00e+00	9.98e-01
e+00	1.03e+00	1.01e+00
e+00	1.00e+00	1.00e+00
e+00	1.00e+00	9.99e-01
e+00	1.00e+00	1.00e+00
e-01	9.98e-01	9.98e-01
e+00	1.00e+00	1.00e+00
e-01	1.00e+00	9.99e-01
'e-01	9.97e-01	9.97e-01
e+00	1.00e+00	1.00e+00
Be-01	9.95e-01	9.95e-01
e+00	1.00e+00	1.00e+00
e-01	9.99e-01	9.99e-01
e+00	1.00e+00	1.00e+00
e+00	1.00e+00	9.98e-01
e+00	1.00e+00	1.00e+00

### sus RESRAD 5.61. Results are the

n	Beef Ingestion	Milk Ingestion
01	1.54e+00	1.16e+00
02	1.64e-04	1.64e-04
00	2.02e+00	2.02e+00
01	9.34e-01	5.25e-01
01	7.43e-01	7.43e-01
<u>01</u>	6.27e-01	4.77e+00
01	5.28e-01	5.28e-01
01	1.70e+00	7.08e-02
<u>01</u>	1.70e+00	7.09e-02
01	4.24e-02	8.47e-01
01	1.36e+06	1.63e+04
01	1.50e+02	₹.76e+01
01	1.02e+00	1.02e+00
01	7.44e-01	9.76e-01
<u>01</u>	7.43e-01	9.75e-01
00	5.75e+00	2.30e+00
<u>86</u>	5.78e+00	2.34e+00
00	5.76e+00	2.30e+00
01	5.64e-01	1.25e+00
02	7.04e-02	3.52e-01
01	2.26e-01	4.06e-01
01	2.26e-01	4.08e-01
00	2.77e+00	2.21e+00
00	1.50e-01	2.51e+00
<u>00</u>	1.51e-01	2.51e+00
00	1.51e-01	2.51e+00
00	1.51e-01	2.51e+00
01	2.94e-03	1.47e+00
00	1.41e+00	2.40e+00
00	1.41e+00	2.40e+00
00	1.41e+00	2.40e+00
<u>00</u>	1.41e+00	2.40e+00
00	1.41e+00	2.40e+00
00	1.41e+00	2.39e+00
01	5.95e-02	1.08e+00
02	1.87e-04	3.75e-03
<u>02</u>		3.54e-03
<u>02</u>		3.54e-03
02		2.70e-03
02		3.54e-03
02		4.58e-03
<u>00</u>	1.70e-01	4.84e-01

